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THE PROLONGED ADMINISTRATION OF ARTIFICIAL RESPIRATION.*

BY

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RECENT HISTORY OF ARTIFICIAL RESPIRATION.

Until 1928 (1) artificial respiration had been administered either manually or by some sort of bellows, or insufflating apparatus.

The manual method was brought to its present state of development by Sir E. A. Sharpey Schäfer. The obvious defect in Schäfer's method is that the chest is deflated and then allowed to return to the normal position through its inherent elasticity. This process is exactly the reverse of normal, and if for any reason the tone of the respiratory muscles becomes impaired, the results are ineffective.

Bellows devices (2) as well as the lung-motor and pulmotor which force air in and out of the lungs have been largely discredited and discarded (3) in this country and Canada.

Thunberg's (4) "barospirator" works on an entirely new physiological principle. The patient is placed in a chamber

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in which the pressures are alternately raised and lowered about 75 cms. of water. As the pressure changes on both sides of the thoracic wall are equal, the patient breathes literally without moving his chest. Though the volume of air in the lungs remains constant, the mass of air is increased with a rise in pressure and diminished when the pressure falls, thus simulating the usual respiratory exchange.

In 1889 Doe (5) described an apparatus devised for resuscitating asphyxiated infants. It consisted of a small box, over an opening in which a rubber dam was stretched. Through a hole in the dam, the infant's nose and mouth protruded. By means of a rubber tube connected to the box, a person outside blew in and sucked out air, causing alternate exhalation and inhalation.

In 1918, Steuart (6) suggested the use of a mechanically operated device for inducing artificial respiration in children with infantile paralysis. To quote the author: "The principle used is to place the child's thorax and abdomen in a rigid air-tight chamber communicating with a large bellows, which periodically causes a partial vacuum in the box." Either positive or negative pressures, or both, were obtainable and could be regulated as to frequency and amount.

In 1928 Eisenmenger (7) of Vienna patented a respiration device consisting of a rigid leather dome-shaped piece lined with rubber. This was strapped tightly over the patient's chest from the region of the clavicle to the umbilicus. Alternate positive and negative pressures inside the dome were then applied by an electrically driven pump.

EARLY LABORATORY EXPERIMENTS.

Our interest in these matters was aroused by inquiries from our friends at the Children's Hospital in Boston, who wanted some method, physiologically sound and perfectly comfortable, for giving artificial respiration to children in respiratory difficulty from the intercostal paralysis caused by poliomyelitis. Regarding this condition, Dr. J. L. Wilson (8) states that "Of all the experiences that the physician must undergo, none can be more distressing than to watch respiratory paralysis in a child with poliomyelitis—to watch him become more and more dyspneic, using with increasing vigor

every available accessory muscle of neck, shoulder, and chin —silent, wasting no breath for speech, wide-eyed, and frightened, conscious almost to the last breath."

In January, 1927, one of us was using a body plethysmograph in recording respiration of the cat. This device consisted of a metal box in which the animal's body was enclosed with its head protruding through a hole in a rubber sheet or collar. The volume changes of the chest, which are equivalent to the volume of air respired, were recorded by the movement of a spirometer attached to the plethysmograph. While the principle employed was not original, its application as a means of making accurate quantitative and qualitative records of the respiration proved very effective.

It occurred to us that this apparatus might be used to test the effect of alternate positive and negative air pressures in causing artificial ventilation of the lungs. Therefore we curarized [1] a cat which lay in the plethysmograph in order to inhibit voluntary respiration, and then applied alternate positive and negative pressure to the air in the plethysmograph by means of a small piston pump. By this means we were able to produce sufficient lung ventilation to maintain the animal in perfect condition.

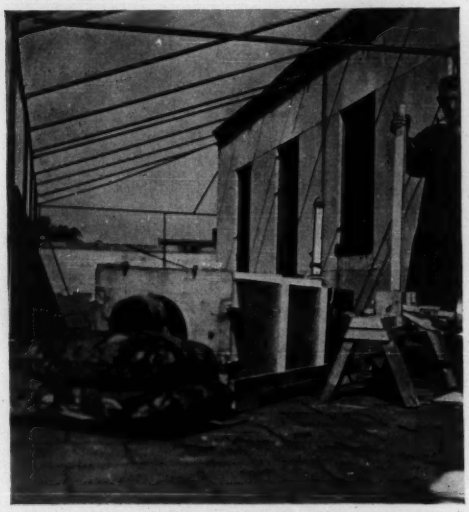
The results of this experiment were presented to friends in the Consolidated Gas Company of New York and its affiliated companies. This group appreciated, as probably no other did, the practical possibilities of a method for applying artificial respiration over long periods. Like ourselves they had but faint hope that our results would ever be of medical interest. Their rescue squads were called upon constantly to administer artificial respiration, combined with O_2-CO_2 inhalation, to patients in respiratory difficulty from such widely differing causes as severe carbon monoxide poisoning, electric shock, drowning, infantile paralysis, asphyxia of the new-born, acute alcoholic poisoning, drug poisoning, and the like. They gave us at once, through their Liability Insurance Fund, the small sum requested and with this money we made the first respirator shown in Fig. 1.

It consisted simply of a cheap galvanized iron box with a rubber collar made specially by the Hood Rubber Company

[1] Curare paralyzes the respiratory muscles.

of Watertown, Massachusetts. With this machine, equipped with household vacuum cleaners as the source of pressure, and hand-operated valves, we produced on the first subject tried the five-minute apnea shown in Fig. 2. This experiment and many others which followed convinced us that the method might have clinical application. The Gas Company's Lia-

FIG. 1.

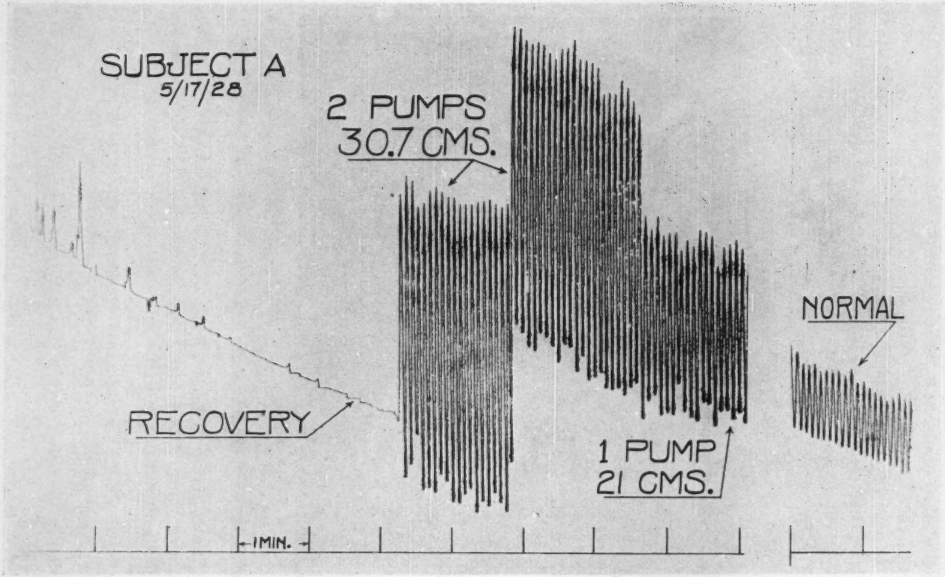


First respirator, May, 1927, consisting of cheap galvanized iron box, with bed made from "garage creepers" and two household vacuum cleaners with hand-operated valve as the source of alternate positive and negative pressure. U-tube manometer is standing on top of the respirator box.

bility Insurance Fund then gave us a generous donation with which to make a respirator for use in a hospital in Boston where we could conveniently put it to clinical trial.

In the spring of 1928, the machine shown in Fig. 3 was built and used extensively in our laboratory on normal men and women. Our first task was to determine what pressures were required to induce respiration in normal persons, and

FIG. 2.



The effect on a normal man of the respirator as shown by the Benedict Portable Metabolism Apparatus. Record reads from right to left. Abscissæ represent time and ordinates oxygen. Note the immediate cessation of respiration (apnea) beginning at "Recovery" and the pronounced oxygen consumption during this recovery. (Courtesy *J. Clin. Investigation.*)

above all to develop a rubber collar which would not be uncomfortable about the patient's neck, but at the same time would effect an air-tight seal (Fig. 3*a*).

It may be of interest that we obtained the optimum diameter of the rubber collars from frequency curves plotted from data given us by the Cluett Peabody Company (collar manufacturers) on their sales of various sizes of collars, and the

FIG. 3.

Second respirator, May, 1928. The collar and headrest are in place and the patient ready to be pushed into the body of the machine. Foot end can be raised or lowered to give change in position. Arm ports are on top and on side not visible. (Courtesy *J. Clin. Investigation.*)

optimum diameter of the head hole in the lid or front of the machine, from the Knox Hat Company. It seemed impossible to obtain data of this sort from medical sources.

EXPERIMENTS WITH PRESSURES.

In the application of the Schäfer Prone Pressure method probably no other group has attained the proficiency of the Rescue Squads of the Consolidated Gas Company of New York. Their supervisor of resuscitation, Mr. T. J. Shaugh-

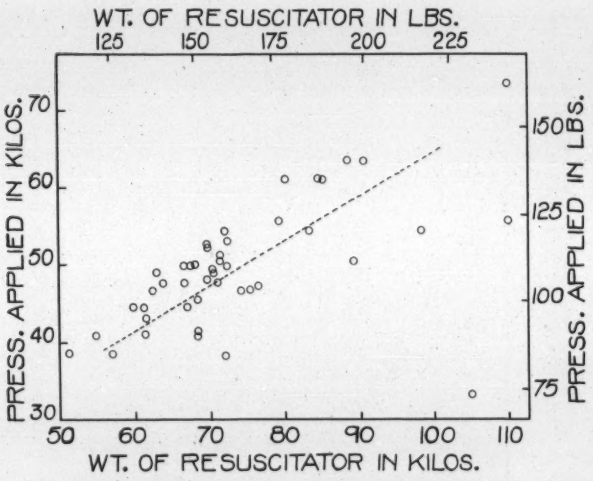
FIG. 3a.

Head of respirator showing adjustable head rest and "built-up" rubber collar. Six sizes of collar were needed. Present machines use one or two sizes moulded flat, with simple mechanism for stretching in order to change the diameter of the head hole. (Courtesy *J. Clin. Investigation.*)

nessy, had these rescue men, forty in number, perform the Schäfer method using the platform of an excellent spring balance as the subject in order to determine the pressures exerted upon the chests of their subjects in actual practice. Their average results, plotted against the weight of the operator, are shown in Fig. 4, and indicate that an experienced 150-pound man pushed down upon his subject with a force of about 100

pounds. This force is applied over the palms of the two hands (roughly 25 to 30 square inches) giving a pressure of about 3 to 4 pounds per square inch (200–250 cms. of water). Experience has shown that these pressures should be applied at rates of about 12 to 15 a minute. While it is well known that the method is of great practical value in rescue work, it is obviously inapplicable to long continued use.

FIG. 4.



A comparison of the weights and pressures applied by experienced "Prone Pressure Resuscitators" from the resuscitation crews of the Consolidated Gas Company of New York. (Courtesy *J. Clin. Investigation.*)

In Fig. 5 are shown the effects on normal humans of various pressures alternating between positive and negative in equal amounts. In general it was found that pressures less than 7 cm. (approximately) were not noticed by the subject, while anything above this value increased the amount of air breathed by the subject. The subjects of course were not aware of the way in which the machine was being run, and were exhaling through an appropriate valve and pipe line

arrangement into a very sensitive spirometer which collected all their exhaled air. All of them breathed normal room air at normal temperature and pressure.

It was found that 7 cm. pressure was also the approximate threshold for effect upon speech. We talk only on exhalation so that if an unexpected breath or inhalation caused by the

FIG. 5.

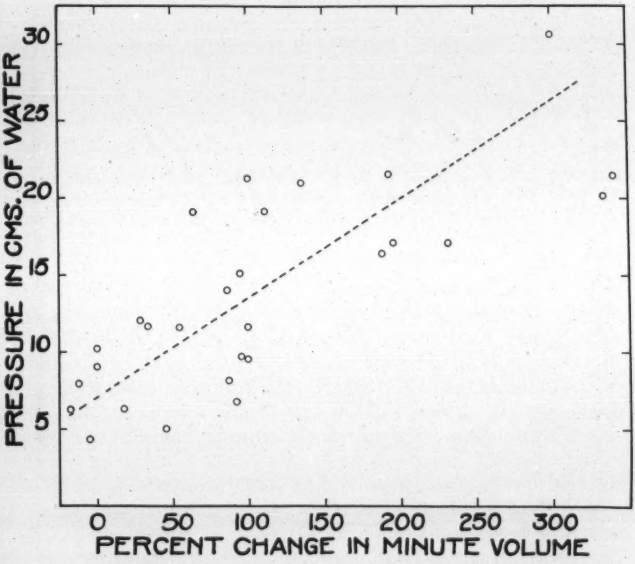
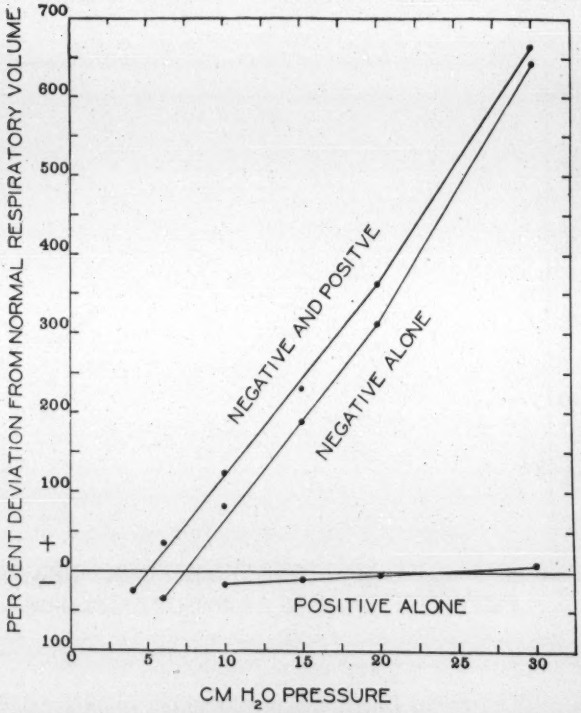


Chart showing approximate threshold pressures at which the respiratory movements of the average subject fall into perfect synchronism with the pump. (Where the dotted line passes through zero is the approximate threshold pressure.) (Courtesy *J. Clin. Investigation.*)

machine interrupts speech, it is proof that our voluntary control of respiration has been lost and is under the artificial control of the respirator. This voluntary control of the respiratory movements, whether it be in a full grown, well developed athlete, or in an underdeveloped child, was lost at pressures in excess of about 7 cm. of water.

Later we showed that fully as good results could be expected from pressures alternating between negative and atmospheric as those from positive to negative. Our results on animals are shown in Fig. 5*a* and were obtained on curarized

FIG. 5*a*.



Respiratory response of curarized cats to different pressures. Note that threshold pressures are about the same as for normal humans (Fig. 5). (Courtesy *J. Clin. Investigation.*)

cats. In more recent work, Favill and Fentriss (9) have shown that alternate positive and negative pressures may sometimes be advantageous clinically in the treatment of infantile paralysis.

THE WORK DONE IN BREATHING.

If the human body is considered as an engine, the efficiency with which it performs work is measurable by appropriate and well known thermodynamic and calorimetric methods. Obviously a certain fraction of the body's fuel consumed in keeping alive must go towards breathing. This fraction we attempted to determine by first finding the normal rate of oxygen consumption of a healthy person lying comfortably on the bed of the machine but without the pumps running. The pumps were then started and a second determination of oxygen consumption was made at pressure variations of about 10 to 12 cm.—just enough for the subject to feel that the machine was taking charge of the mechanism of breathing. A comparison of the results by the two methods invariably were inconclusive and simply confirmed the efforts of previous investigators who had found that the muscular work expended in breathing is but a very small fraction of the total energy normally expended by the body.

FIRST CLINICAL USE OF THE RESPIRATOR.

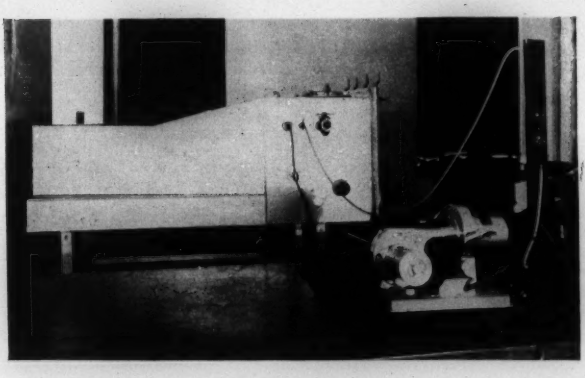
At the Children's Hospital, Boston, in the autumn of 1928, the respirator with which we made these preliminary studies was used on a little girl brought in by the Harvard Infantile Paralysis Commission. She was suffering from respiratory failure caused by infantile paralysis. We kept this child alive for five days, but she finally died of cardiac failure which autopsy showed was probably induced by a unilateral hypostatic pneumonia (10). All of us were then convinced that with certain improvements and changes a machine of this type would be well worth trying for clinical purposes.

In the spring of 1929 the machine shown in Fig. 6 was donated by the Liability Insurance Fund to the Bellevue Hospital, New York City, and installed in their accident ward. On May 29 the hospital staff, assisted by Mr. Shaughnessy of the Gas Company, using this machine, saved the life of a young woman who had been accidentally poisoned by a drug resembling morphine (11).

The Liability Insurance Fund then ordered fourteen machines which they planned to donate to various hospitals in New York City. In September, 1929, a senior at Harvard

College who had poliomyelitis was brought to the Peter Bent Brigham Hospital, Boston, by Drs. Aycock and Kramer of the Harvard Infantile Paralysis Commission. We borrowed one of the Gas Company's unfinished machines from the maker, Warren E. Collins, Inc., of Boston to use on this patient. He was kept alive by the machine for two or three weeks, after which he used it less and less. He graduated later from Harvard, and now walks, almost unaided, goes to work down town, drives a car, and what is more important, has been in good health constantly since his dismissal from the hospital. This case, reported by Shambaugh, Harrison, and Farrell (13) is apparently the first ever to be described in medical literature.

FIG. 6.



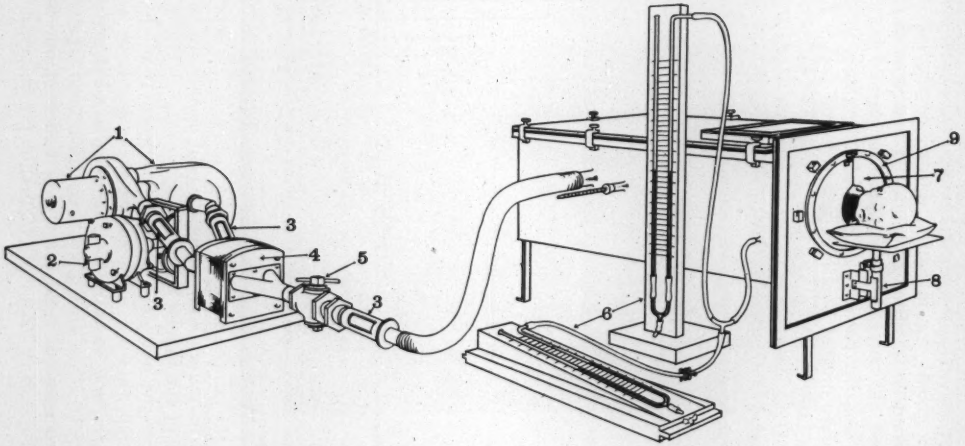
Respirator installed in 1929 in the Bellevue Hospital, New York. (Courtesy of the Liability Insurance Fund.)

From this point on we were assured of the intelligent use of the machines more or less throughout the country. Today there are about 150 in the United States and Canada, and one in London, while Professor August Krogh of Copenhagen, using our drawings and specifications, has made one with some ingenious improvements.

RECENT USE OF THE MACHINE.

The development of the infant sized model (Fig. 7) followed closely that of the larger one. This machine we in-

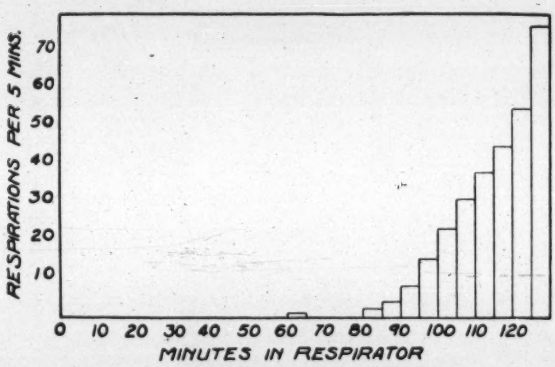
FIG. 7.



Infant respirator. 1, pumps; 2, motor; 3, vents; 4, alternate; 5, valve; 6, manometers; 7, external shutters; 8, adjustment for head rest; 9, adjustable ring to hold collar in place (the external shutters are used occasionally to reduce movement of the rubber collar). (Courtesy *J. of Clin. Investigation.*)

tended for use on babies up to two years of age, though now it is used chiefly for initiating normal respiration in newborn babies who breathe with difficulty or not at all (Fig. 8). At first we did not know what pressures would be required nor how long the patients might have to remain in the machines before normal breathing was restored (14). The machine has been developed as shown in Fig. 9 in coöperation with Dr. D. G. Murphy of the Pennsylvania Medical School. He and others have described it fully (14), (15).

FIG. 8.



Frequency of spontaneous breaths of infant No. 4 during period of artificial respiration, prior to onset of rhythmic breathing. The base line indicates the period of artificial respiration expressed in minutes. The ordinate records the number of breaths for each five minute period. Note the long absence of spontaneous breathing, and the relatively constant increase in breathing frequency following the latter. (Courtesy *Jour. Amer. Med. Assoc.*)

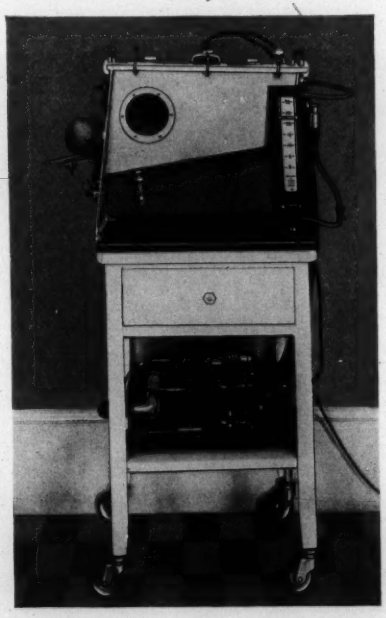
Since the infants are put in naked and must be kept warm, four electric bulbs, giving adequate heat, are connected up at the inside of the hinged lid.

Because the machines become the property of the hospitals in which they are installed, we no longer have access to case reports, and have no accurate idea to what extent they are used. In New York City there have been treated, with a fair percentage of total recoveries, well over one hundred cases of respiratory failure not caused by poliomyelitis—these

cases include unusually severe carbon monoxide poisoning,[2] drug poisoning, acute alcoholism, drowning, electric shock, and the like.

In Boston alone we have given respiratory treatment in at least a hundred cases of poliomyelitis, while New York

FIG. 9.



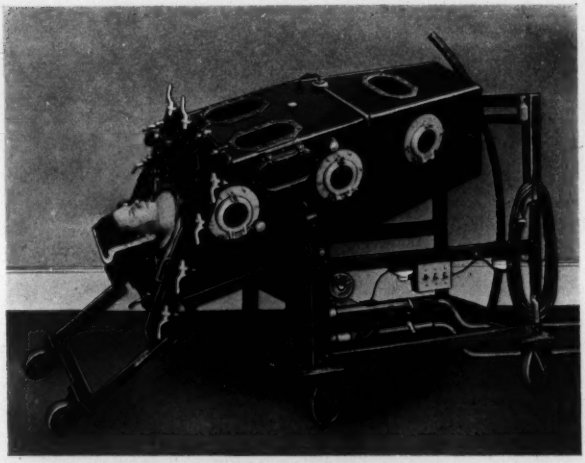
Infant respirator with doll as patient. Note that the bed is inclined downward about 20° as in cribs for newborn infants. This is to facilitate drainage of mucous. About 50 of these machines are in use.

City, with over twenty machines in use last summer, has probably exceeded this number. In poliomyelitis, the outstanding work with the machines has been done by Dr. James L. Wilson (8), (16), (17), at the Children's Hospital, Boston.

[2] For the average case of gas poisoning the respirator is no better than the O_2-CO_2 inhalation method developed by Henderson and Haggard of Yale University.

In two years, he has treated twenty-three intercostal cases with three deaths in the hospital and two deaths from pneumonia after the patients had left the hospital. He has treated also twenty bulbar cases with seven good recoveries. All forty-three of these were desperate cases and most of them probably would have died without the machines.

FIG. 10.



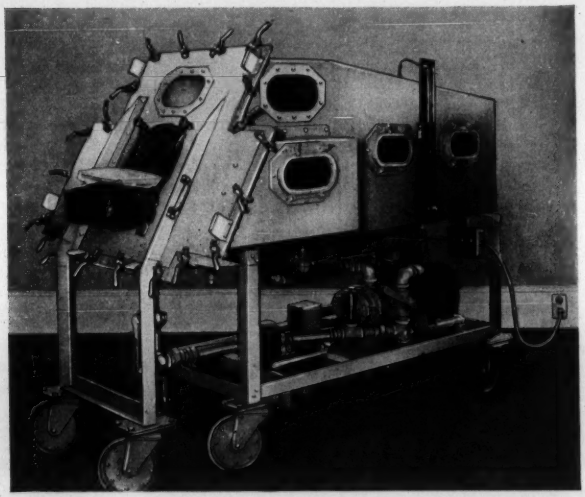
Respirator which can be tilted and rotated. (Courtesy of Children's Hospital, Boston.)

Wilson and his associates have shown that respirators in the future should be so made that they can be tilted foot up 20° from the horizontal and rotated 30° either way. These adjustments allow changes in position of the patient which facilitate drainage of mucous, and prevent hypostatic pneumonia (Fig. 10). The advantages of this procedure were forecast by Murphy, Drinker, and Drinker (18), as the result of animal experimentation but, prior to Wilson's work, had not been shown clinically.

Dr. Arthur T. Legg of the Children's Hospital, Boston, has shown that promising results are obtained in the daily

use of respirators in the recovery treatment of poliomyelitis patients. A true case of intercostal paralysis apparently rarely regains perfectly normal respiration. Legg now has numerous instances in which former respirator patients have entered his after-care Clinic with chest expansions of ½ inch or so; at the end of six months or less, this expansion has been increased as much as 2½ inches. In order that such patients might be placed with arms extended, a respirator was built with special side arms (Fig. 11).

FIG. 11.



Orthopedic model used in after-care of poliomyelitis patients. (Courtesy of Children's Hospital, Boston.)

SUMMARY.

A review and brief history, with bibliography and illustrations of the development of the apparatus described.

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THE VIBRATIONS OF A CIRCULAR PLATE

BY

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The mathematical theory of a circular Chladni plate has been worked out by Kirchhoff and is given in Rayleigh's "Sound." [1]

The differential equation is

$$(\nabla^4 - k^4)w = 0 \qquad (1)$$

and the solution gives a nodal system composed of n diameters denoted by

$$\cos(n\theta - \alpha) = 0 \qquad (2)$$

with the concentric circles whose equation is

$$J_n(kr) + \lambda J_n(ikr) = 0. \qquad (3)$$

Equations (2) and (3) show that a plate may be vibrated so as to give any number of circles or radii and any combination of these. So long as the circular plate was vibrated with a violin bow it was impossible to force the plate into oscillation of very high frequencies—hence only a few circles or radii could be produced upon a circular plate. With a vacuum tube oscillator,[2] many figures may be produced which have not been discovered heretofore. Curiously enough, although many circles may be formed, no figures composed of radii alone have as yet been found with the electric oscillator.

Some of the nodal circles from high vibrations are given in Fig. 1.

In Fig. 2, several other nodal curves are shown which are not accounted for by Kirchhoff's equation. The second nodal curve from the center is not a circle as required by theory.

[1] Rayleigh, "Sound," Vol. 1, pp. 359–360.

[2] Colwell, *Phil. Mag.*, Vol. 15, No. 76, p. 320.

FIG. 1.

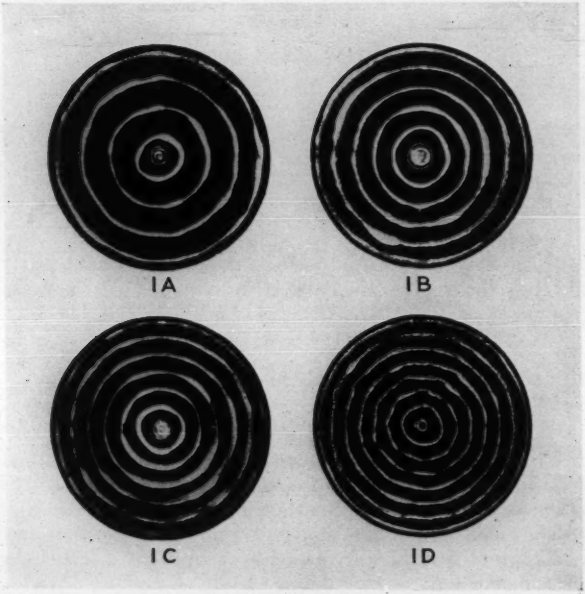


Fig. 1A, 4 circles.
Fig. 1B, 6 circles.
Fig. 1C, 7 circles.
Fig. 1D, 8 circles.

FIG. 2.

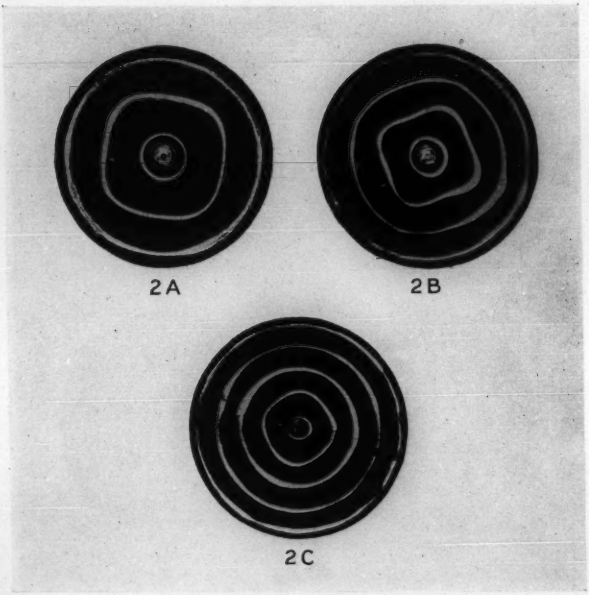


Fig. 2A, 3 nodal lines.
Fig. 2B, 4 nodal lines.
Fig. 2C, 5 nodal lines.

Figure 3 shows a dozen different curves on a circular plate which are neither radii nor circles.

FIG. 3.

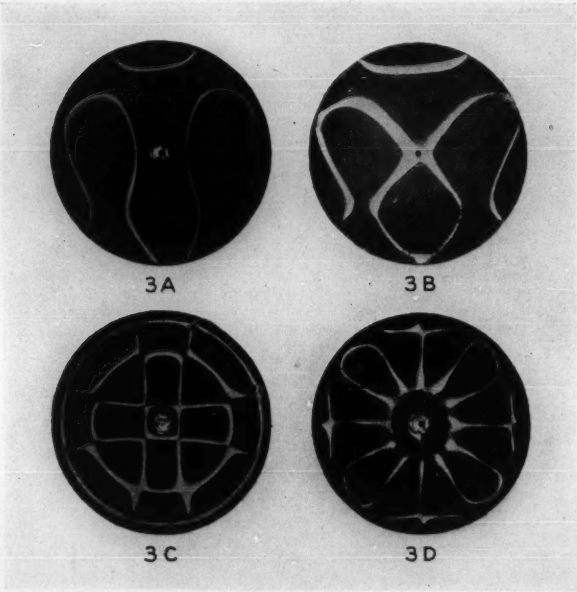


FIG. 3—*Continued.*

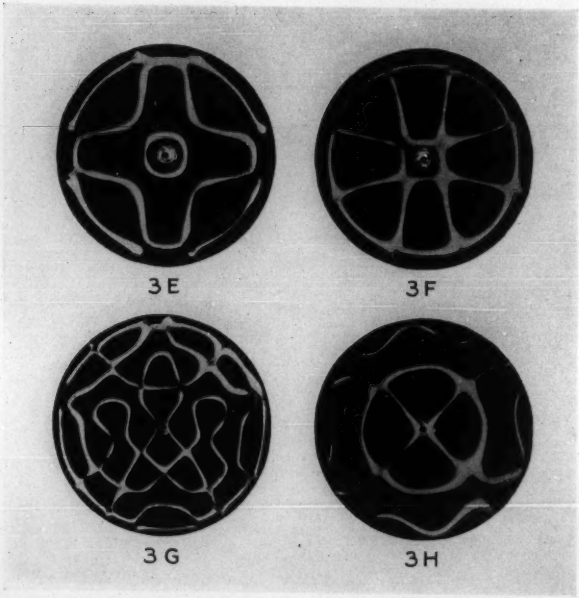
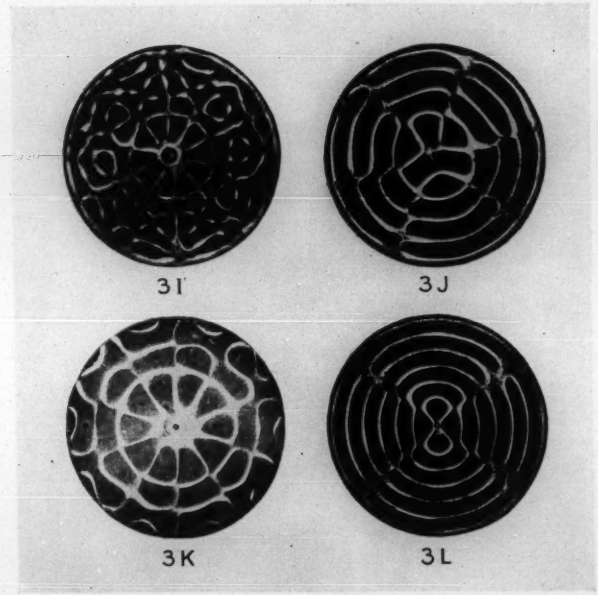


FIG. 3—*Continued.*



The curves of Fig. 4 are combinations of circles and radii which satisfy the mathematical equations. A comparison of Figs. 4G and 4I will show how a very slight change in the sand nodes makes two plates look very different, although the two vibrations are very much alike.

FIG. 4.

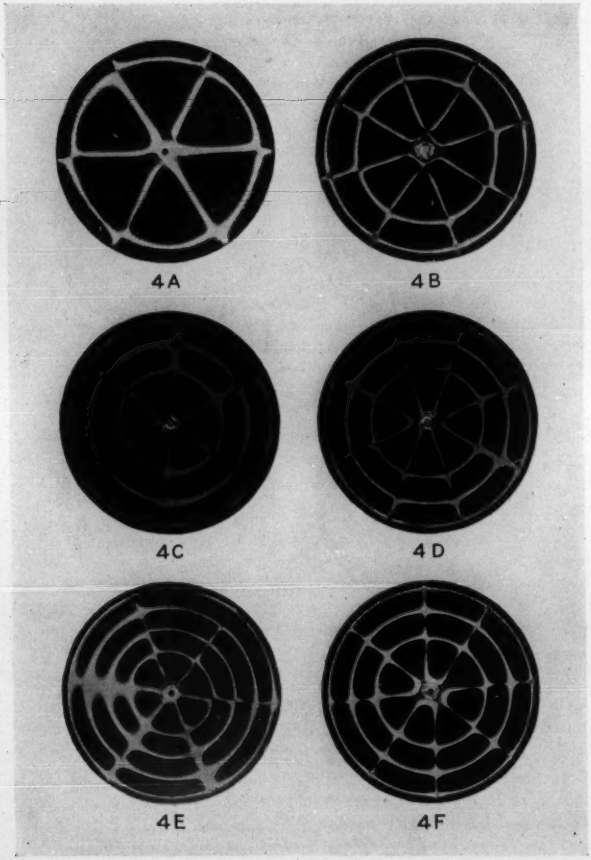


FIG. 4—*Continued.*

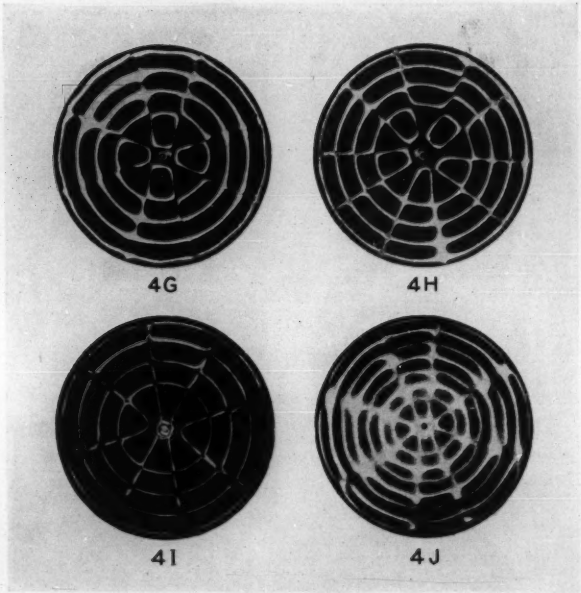


Fig. 4A, 3 diameters, 1 circle.
Fig. 4B, 4 diameters, 2 circles.
Fig. 4C, 3 diameters, 3 circles.
Fig. 4D, 4 diameters, 3 circles.
Fig. 4E, 3 diameters, 4 circles.
Fig. 4F, 4 diameters, 3 circles.
Fig. 4G, 4 diameters, 4 circles (approximately).
Fig. 4H, 5 diameters, 4 circles.
Fig. 4I, 4 diameters, 4 circles.
Fig. 4J, 4 diameters, 7 circles.

AUTOMATIC TRAIN CONTROL BASED ON MAGNETIC BRIDGE.

BY

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Formerly Chief Engineer,
Miller Train Control Corporation.

ABSTRACT.

This system of automatic train control employs an alternating magnetic Wheatstone bridge for receiving stop indications from inert track inductors, whereby air brakes of a train approaching a danger zone are operated to stop the train. The bridge is a reversible variocoupled transformer, and the inductor is a flux-reverser and phase shifter. A "reflector" reactor at the signal permits clear indications of the train control and prevents false clear indications if the cable between the reflector and the inductor should become short-circuited. The magnetic bridge is adaptable to many uses in other industries, and is extensively used for detecting vehicles in street traffic control systems.

INTRODUCTION.

A perfectly safe railroad runs no trains. Train operation involves risk. More trains involve more risk—unless safety appliances are used. Automatic air brakes and automatic block signals, originally encouraged by governmental edicts, have been extensively used, and on busy railroads are economic necessities. Today all American railroads use air brakes; all Class A railroads use automatic block signals. They consider these safety appliances profitable. In fact, the American Railway Association now has formulas by which their members can calculate the monetary advantage of installing signals, where traffic capacity is needed. Automatic train control is the connecting link between the automatic block signals and the automatic air brakes, for train control equipment is controlled by the wayside signal system and it actuates the air brake apparatus when danger conditions are not acknowledged by the engineman.

In 1914 the Chicago and Eastern Illinois Railway had a division of its road equipped with a ramp type of train control.[1] In 1922 the Interstate Commerce Commission,

[1] "Miller Automatic Train Control," *Ry. Sig. Eng.*, **15**, 109–10 (1922).

which had been impressed with the safety record of this railroad and the desirability of train control, acted on a Congressional order and decreed [2] that 49 of the important railroads should equip one division each with train control, conforming to certain specifications which the Commission prepared. Many systems of train control were invented. At least a dozen schemes were given trials by the railroads who spent millions of dollars coöperating with manufacturers. None of the proposed schemes, however, met fully the original requirements of the Interstate Commerce Commission, particularly in respect to the rule that failure of any essential part should result in an automatic application of the brakes. This ideal, so much sought for in air brakes, signals, and train control has been approximated well enough by nine systems of train control. These fall into five classes: the continuous inductive; the intermittent electrical-mechanical contact; the permanent magnet; the dynamic inductive; and the alternating current intermittent inductive. The Interstate Commerce Commission has approved installations of these devices.

Since the installations of these devices by the Class A railroads, fatalities due to collisions have been greatly reduced, in spite of the record-breaking traffic of the period. This safety objective of Congress has been attained. Unfortunately no single type of train control would satisfy the demands of all the railroads; and most of the devices, as installed, are not interchangeable.

The most elaborate continuous inductive system [3] with cab signals and air brake control costs approximately $3000 per locomotive, and up to $3000 per mile of track. The continuous inductive scheme is likened to a wireless telegraph system, the rails serving as transmitting antennæ, while loop antennæ carried by the locomotive serve to control amplifiers and other equipment which operate cab signals and air brakes.

The intermittent electrical-mechanical contact system [4] employs a ramp or third rail whose potential is controlled by

[2] Order No. 13413, Interstate Commerce Commission.

[3] "Union Switch & Signal Company's Automatic Train Control System," *Ry. Review*, 70, 348–50 (1922). "Automatic Train Control on the Chicago & Northwestern," *Ry. Sig.*, 21, 448–55 (1928).

[4] "Regan Automatic Train Control Systems," *Ry. Rev.*, 70, 337–41 (1922).

the wayside signals. A shoe carried by the locomotive engages the ramp; and the ramp battery, if connected, energizes a magnet on the locomotive to prevent actuation of the brakes at clear signals.

Two systems employ permanent magnets [5] on the track to control air brake actuators on the locomotive. If the signal is clear, an electro-magnet near the permanent magnet prevents the actuation of the brakes.

A much used form of control utilizes the dynamo [6] action of a coil on a magnet carried past a laminated iron inductor on the track. A choke coil on the inductor is controlled by the signal system; and when closed prevents the sudden magnetic change that would occur for a stop condition. No roadside energy is required for this system.

The alternating current intermittent inductive type [7] provides a magnetic Wheatstone bridge on the locomotive, while on the track way is an inductor receiving and reflecting electro-magnetic energy from the passing locomotive. A detailed description follows.

A.C. INTERMITTENT TYPE.

The alternating current induction train control with inert track elements was given a preliminary test on a high speed passenger locomotive of the Chicago and Eastern Illinois Railway in 1925. Next, ten locomotives of the New York Central Railroad [8] and twenty miles of track on the Detroit Branch were operated in regular service for a year, during which time the principal train control manufacturers were licensed to manufacture this type of equipment.

In these installations the track elements were located on the right side of the track, near the ends of the ties, and the receiver was secured to the frame of the engine (see Fig. 1).

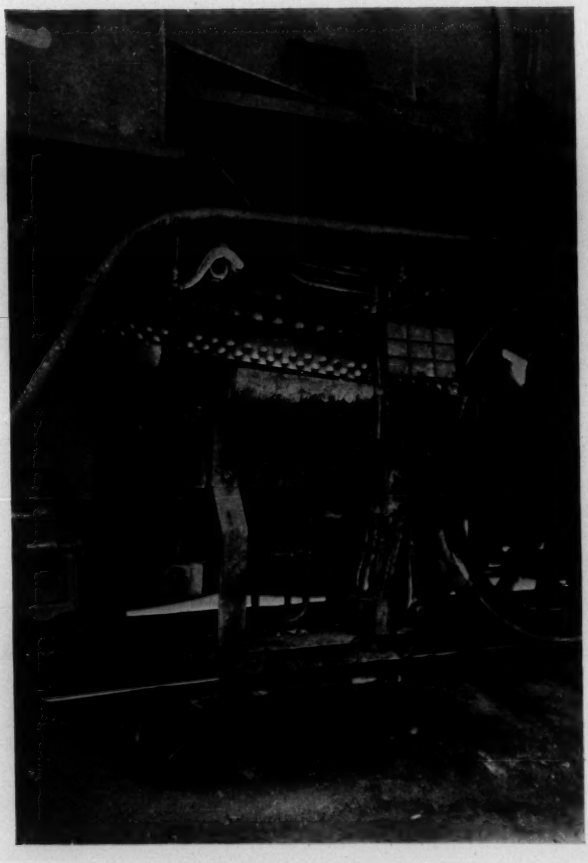
[5] "National Safety Appliance Company's Train Control System," *Ry. Sig. Eng.*, **15**, 111–13 (1922). "Sprague Train Control System," *ibid.*, **15**, 226–30 (1922).

[6] "Baltimore & Ohio Installs G.R.S. Auto-Manual Train Stop," *Ry. Sig. Eng.*, **19**, 395–400 (1926).

[7] U. S. Patent No. 1,806,500. U. S. Patent No. 1,775,051. "Automatic Train Control Bulletin," No. 9, *Amer. Ry. Assoc.*

[8] "New York Central Installs Miller Train Stop," *Ry. Sig.*, **19**, 176–80 (1926).

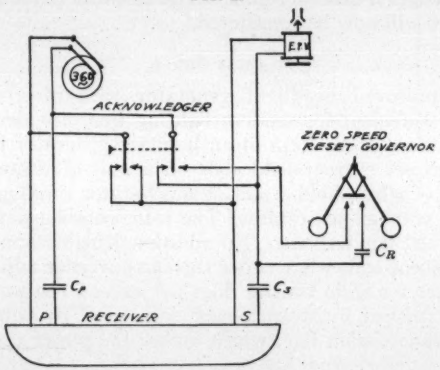
FIG. 1.



Valve box, receiver and inductor on New York Central.

In 1927 the Chicago, Indianapolis and Louisville Railway, known as the Monon, installed this type of train control [9] between Indianapolis and Hammond on a total of 161 miles of single track and 50 engines. The inductors, in this case, are placed between the rails so that each inductor serves a north bound signal and a south bound signal. The receivers are located under the center of the pilots, so that the receiver passes over the inductor before the front wheels of the locomotive can shunt the track circuit controlling the signal for that direction. A description of this apparatus should be of general interest because of the application of the same principles to other industries.

FIG. 2.



Locomotive circuits.

Figure 2 shows the electrical connections between the essential parts of the locomotive equipment. The turbo-generator supplies 360 cycle power to the primary coils of a receiver [10] or detector whose secondary circuit normally energizes a valve magnet which, if released, would cause the air brakes to be applied. Condensers *Cp* and *Cs* improve the

[9] "Monon Automatic Train Stop," *Ry. Sig.*, **22**, 209 (1929). *Ibid.*, **22**, 243 (1929).

[10] "The Three-Circuit Transformer," A. I. E. E. District Meeting, Rochester, April 29, 1931, C. F. Estwick.

power factor of these circuits. A manual control switch on the locomotive is adapted to connect the generator directly to the valve magnet to forestall needless brake applications. And another position of this switch connects the generator to the valve magnet through a condenser and zero speed governor, which admits a large current sufficient to reset the valve magnet after the train has been stopped by an automatic train control application of the brakes.

The Monon Railway dispensed with the reset governor by the substitution of a manually operated reset contactor on the side of the locomotive. Many other modifications are possible, and tapered speed control adjuncts could be added to enforce reduction of speed even though the engineman acknowledges a caution signal. The essential parts and their principles will now be considered.

360 CYCLE SUPPLY.

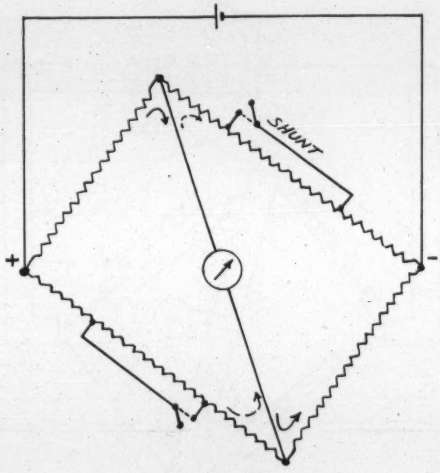
An improved headlight generator with direct current capacity sufficient for modern lighting was provided with a small section in the form of an inductor generator having a pair of direct current field coils on a pair of slotted poles, the slots of which hold a pair of small stator windings generating 32 volts at 360 cycles. The rotor consists simply of a few toothed laminations. No additional maintenance is required except somewhat closer turbine governor adjustment. The power for train control does not exceed 100 watts, and this is furnished by steam power, instead of by batteries or special transmission line, which makes the power cost negligible.

MAGNETIC WHEATSTONE BRIDGE.

Figure 3 shows a conventional electric Wheatstone bridge in which a galvanometer or other electricity detector connects two points of equal or unequal potentials on the resistances. If adjusted as shown for normal unbalance, connection of the shunts may cause the bridge to become balanced or even reversed, so that currents cease or even flow backward through the detector. Similiarly, in Fig. 4, a magnetic Wheatstone bridge is shown. A primary magnetizing coil drives flux through the reluctances. If a magnetism detector, such as a secondary core with detector coil and alternating current

galvanometer, be connected to points of normally unequal magneto-motive force, the detector will normally be energized as shown by the solid arrows. Now if iron inductors are introduced in the higher reluctance paths, the bridge may be balanced or reversed, and secondary flux will cease or reverse its direction through the secondary core. This re-direction is equal to a 180 degree reversal of phase with respect to the primary magneto-motive force normally impressed on the secondary core.

FIG. 3.



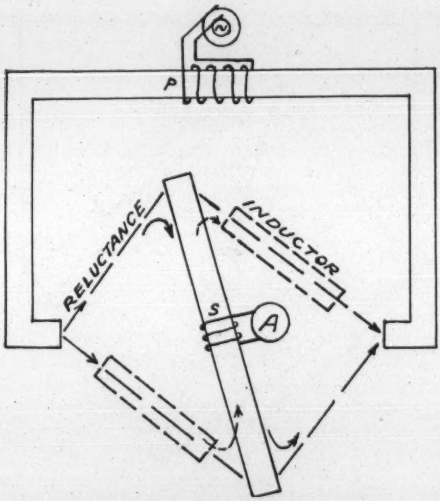
Electrical analogy.

Figure 5 shows the magnetic bridge in a more practical form. It now appears that the flux through the secondary core traverses a figure of eight path. The magnet E.P.V. normally keeps closed the air valve shown; but if the longitudinal reluctance should be decreased by a track element to equal approximately the lateral reluctance, the bridge would become balanced and the valve would be released.

In this discussion we will speak of lateral force and longitudinal force. It should be clear that calculation of

magnetic forces is based on the product of flux times reluctance, in the same way that *IR* drops are calculated in an electric bridge. The lateral force mentioned herein is the total force minus the flux reluctance drop in the longitudinal reluctance. The remainder, which is the total minus the flux reluctance drop in the lateral reluctance, is called the longitudinal force. The lateral force from the right end of the primary core is impressed on the near end of the secondary

FIG. 4.

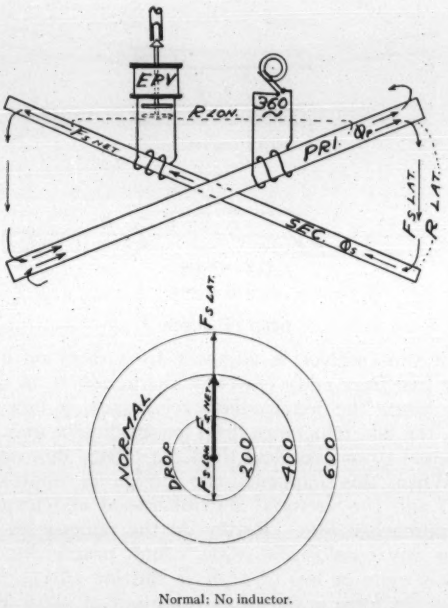


Elementary magnetic Wheatstone bridge.

core; the longitudinal force from the right primary pole acts at the opposite end of the secondary core. Therefore, the net force acting to drive flux through the secondary core is the vectorial sum of the lateral and longitudinal forces, as shown on the vector diagram of Fig. 5. Here the lateral force is shown as 600 special force units, and the longitudinal force in the opposite direction is shown as 200 units, the vector sum being 400 units, corresponding to the normal current of

400 milliamperes in the valve magnet circuit. This current is sufficient to keep the valve closed, with ample margin for variations in turbine speed and jolting of the locomotive. The valve releases at 200 milliamperes. In an electric bridge the currents are generally confined to well-defined paths which can be represented in one plane. In the magnetic bridge the

FIG. 5.



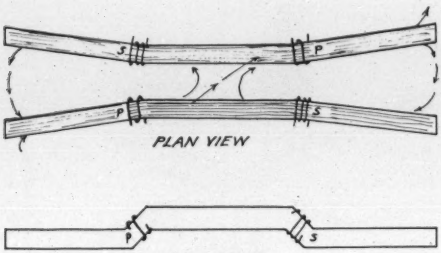
Normal: No inductor.

flux occupies an infinitely large space about the primary core, but for the purposes of this illustration the flux can be considered conveniently as lying in one horizontal plane.

In actual construction the cores are not crossed, but parallel (see Fig. 6). But the two primary coils are placed on diagonally opposite poles, and the two secondary coils on the other diagonal, so that the flux through the secondary coils

traverses a figure of eight path as before, jumping air gaps between the central "coupling" areas of cores, as well as at the ends of cores. This distribution of reluctances permits a very practical construction in a limited space. However, the fundamental principles are not changed and the crossed cores will be used in the illustrations of phase angles.

FIG. 6.

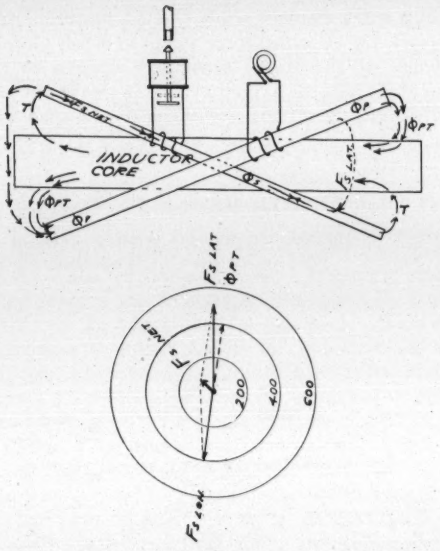


Cores for receiver.

DEAD INDUCTOR.

When the receiver is adjacent to a dead or unwound inductor free from eddy currents, the action is as shown in Fig. 7. Since the longitudinal reluctance is now greatly reduced, the flux reluctance drop longitudinally may become nearly equal to or even less than the lateral flux reluctance drop. When this happens, the bridge is approximately balanced and the vectorial sum of lateral and longitudinal forces approaches zero. Rarely do the reluctances become equal for any considerable time. And, practically, the inductor has more or less of a phase shifting effect. Accordingly, the net force is shown as being out of phase with the lateral flux. This may occur in any direction, according to the relative magnitudes of the lateral and longitudinal forces and the eddy current properties of the system. In some other applications where the inductor possesses considerable eddy current effect in the longitudinal flux path, it is necessary to introduce a corresponding eddy current in the lateral flux path in order to insure exact phase opposition. As the air

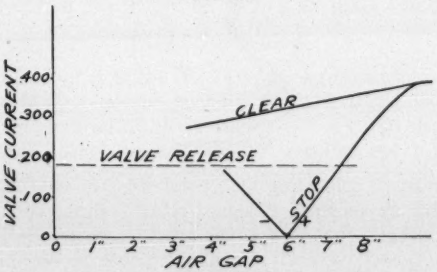
FIG. 7.



Dead inductor.

gap between receiver and dead inductor is decreased, the valve current reduces to a minimum and then rises, as shown in Fig. 8. But it should be noted that the phase angle

FIG. 8.



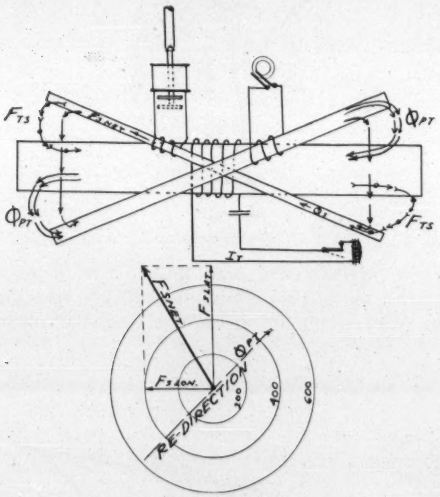
Effect of gap.

reverses at the minimum value of current. If the net force reverses at a track element while the locomotive is travelling at high speed, the reversed force tends to crush more quickly the tendency of the tuned secondary system to continue oscillating at its natural frequency. But this is not necessary as the valve magnet circuit is sufficiently damped to release the valve in less time than that in which a receiver can pass a track element.

CLEAR REFLECTOR.

The track elements are wound with a central coil, as shown in Fig. 9. This inductor coil is connected to a re-

FIG. 9.



Clear, reflected.

flecting system, consisting of a condenser, or of a condenser and reactor as shown. A signal relay contact controls the inductor circuit: first, when the track is clear the inductor circuit is closed; second, when the track is occupied, the

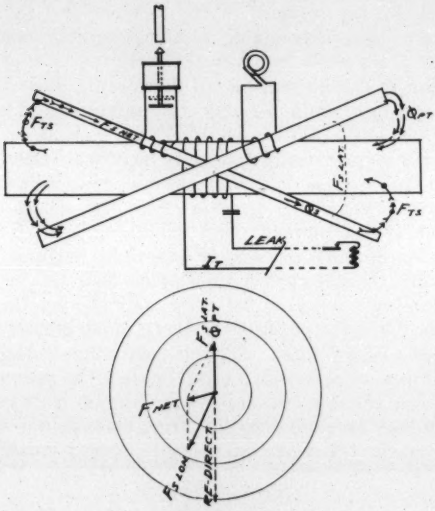
reflector circuit is open so that the reflector can neither be charged nor can it feed stored energy back to the inductor. The reflector has been dubbed an alternating current storage battery because of its rôle. With the reflector connected as in Fig. 9, when a receiver approaches within about ten feet of the inductor, the primary flux induces an appreciable voltage in the inductor coil, which forces oscillations in the inductor-reflector circuit at 360 cycles. The natural frequency of this circuit is slightly lower than 360 cycles and, therefore, the inductor-reflector circuit has lagging characteristics. While the primary of the receiver and the wayside system are thus exchanging electro-magnetic energy, the secondary poles of the receiver are energized by a new route, in addition to the normal lateral flux path. This new route is via the primary, inductor, reflector, inductor, and secondary circuits. Note that the longitudinal force is always re-directed 180 degrees geometrically; and any electrical shifts must be added to 180 degrees. Since the wayside circuit has a lagging power factor when the signal is clear, the reflected energy arrives at the secondary poles substantially out of phase with the longitudinal force or substantially in phase with the lateral force: i.e., at such a time phase that the vector sum of the resultant longitudinal force and the lateral force is large. In Fig. 9 the net force is shown much greater than the normal force of 400 units. This is partly due to the increase of lateral flux, as shown in Fig. 9. When the receiver is not directly over the inductor coil, the minimum clear current in the valve may be somewhat less than normal, but still sufficient to retain the valve in normal proceed condition (see Fig. 8).

EFFECT OF CAPACITY.

In the event that the reflector, or the cable connecting the inductor to the reflector, becomes short-circuited, the reflector cannot be charged by the inductor. Nor could the reflector supply any energy to the inductor (see Fig. 10). Therefore, in so far as the external reactor is concerned, the valve magnet energy cannot be supplied by the wayside system. There remains, however, the inductor coil and condenser which reflect energy to the receiver. The condenser capacity is so chosen that the condenser reactance exceeds the inductive

reactance of the inductor; and, therefore, in case of such a short circuit any energy reflected by the condenser would arrive at the secondary poles substantially in time phase opposition to the lateral energy (see the vectors of Fig. 10). Therefore, the valve current would be reduced and the train would be stopped. In railway safety systems it is desirable to disclose serious defects by stopping the train rather than to allow a possible collision.

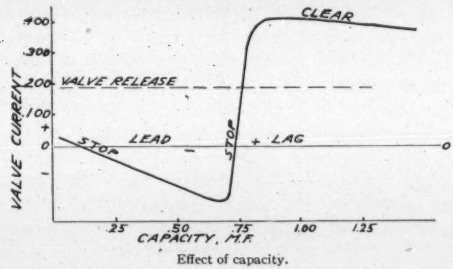
FIG. 10.



Cable short circuit.

Figure 11 shows the interesting effect of varying the capacity of an inductor circuit with a moderate air gap between the receiver and the inductor. The first small amount of capacity reduces the secondary current toward zero. This effect increases with capacity, as shown by the reversed current, until the inductor circuit resonates at unity power factor, in this case at 0.75 microfarad. Then occurs a sudden change. The secondary current rises steeply through

FIG. 11.



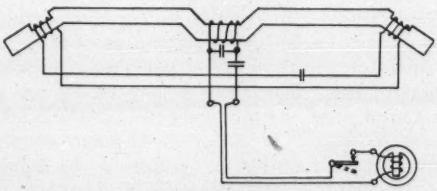
Effect of capacity.

zero (or swings around zero if certain eddy current characteristics are present) to a high current in the normal phase. Further increase of capacity has but little effect.

TRACK ELEMENT.

Heretofore we have shown only the fundamental inductor control circuit connected to the center coil of the inductor. A single coil will control effectively a short inductor, but for large margins of safety it seems desirable to employ an inductor somewhat larger than the receiver; and this requires more than one coil on the inductor core. Figure 12 shows the

FIG. 12.



Complete inductor.

circuit scheme used on the Monon Railway. The center coil is shunted by a condenser which adds considerably to the range of air gaps through which a stop indication could be effected. The series condenser and reflector function as already described. The end coils are connected oppositely

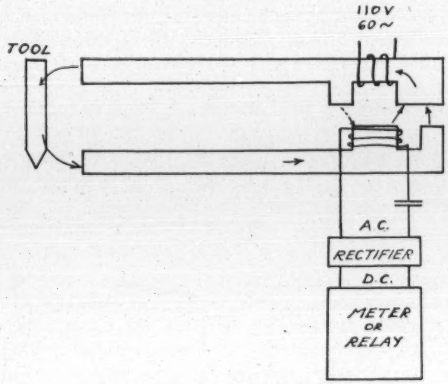
through a condenser, this end coil circuit being generally isolated, as shown. As a receiver approaches the inductor the nearest end coil excites the circuit at a lagging power factor, which tends to give a clear indication in the receiver, for the reason already discussed with Fig. 9. As the receiver approaches the center of the inductor, both end coils become equally excited and since they are connected in opposition the current of the end coils ceases. This leaves the full length of the inductor core effective for collecting receiver flux, thus increasing the effectiveness of the inductor. If inductors of greater length are desired, any number of coils can be put on a core of any length, if the coils are suitably controlled by reflectors and signal contacts. The inductor housing consists of manganese steel because it is tough, non-magnetic, and resistant to eddy currents. Stainless steels and manganese bronzes are also useful in 360 cycle apparatus.

OTHER USES OF MAGNETIC BRIDGE.

When street traffic signals became common motorists, clubs, and state highway departments began to object to the unnecessary delays which ordinary signals inflict on traffic. The Magnetic Wheatstone bridge is being used in many cities to control operation of the signals in accordance with traffic demand, whereby such delays are largely eliminated. Normally the signal favors the more important street, until a vehicle on the cross street approaches the intersection. A 60 cycle "Trafilator" detector, similar to the train control bridge receiver, is buried in the pavement of the cross street where vehicles on the cross street will pass over, or near to, its magnetic poles. The vehicle is actually an inductor, nearly as complicated electromagnetically as the track element of the train control. The structure of some automobiles is equivalent to a clear inductor, because of the lagging characteristics caused by eddy currents induced in the automobile by the detector. This undesirable phase shift in longitudinal flux with respect to the lateral flux of the detector is compensated by introducing an equal phase shift in the lateral flux path at the coupling gap of the detector, so that exact phase opposition and balance are had for the average automobile structure. When a vehicle approaches a detector, a relay

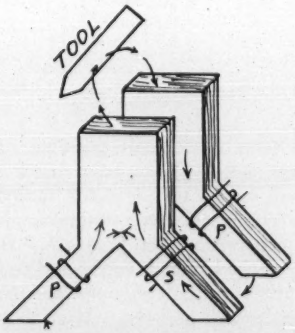
controlled by the secondary circuit of the detector starts the signal timer and the signal reverses, after the usual caution

FIG. 13.



Permeameter for control of heat treatment.

FIG. 14.



Permeameter for magnetic analysis.

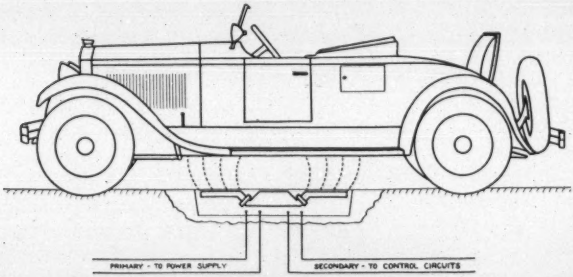
period, so that the right of way is given to the cross street. The cross street period is automatically varied in duration by the number of vehicles passing the detector, up to the pre-

scribed maximum limit. Traffic capacity and facility at many street intersections have been increased by this application of the magnetic Wheatstone bridge, shown in Fig. 15.

In the operation of elevators the problem is not one of collision, but of stopping the elevator car conveniently at the exact floor level. Small magnetic Wheatstone bridges have been installed experimentally on elevator cars for this purpose. Small "dead" inductors of negligible cost are mounted at each floor.

Detectors for indicating the proximity of trains, and for measuring the speed of automobiles, have been demonstrated. The opening of garage doors by the approach of an automobile

FIG. 15.



Showing the magnetic flux from the detector being attracted and redirected by the proximity of a vehicle.

toward a buried detector is easily possible. Small detectors of simplified construction have been used to control heat treatment of steel tools, the detector indicating when the tool has become completely non-magnetic, i.e. when it has passed through the critical temperature. In this case the secondary circuit of the bridge is connected to a milliammeter, which indicates the gradual changes occurring during the decalescent or recalescent periods. After the tools have been heat treated, their hardness can be compared, provided the size, shape, and composition of the pieces are similar. In which case it is quite possible automatically to inspect and reject insufficiently or excessively hardened steel parts passing along a production line (see Figs. 13 and 14).

These applications of the magnetic Wheatstone bridge indicate the variety of arrangements in which the alternating magnetic bridge has been used. Each employs the fundamental flux-reversing principle which was developed for the train control system described; and each involves consideration for phase relations of fluxes in bridge and inductor. Although a complete discussion of the electro-magnetic behavior of this apparatus would be quite involved, yet it should be noted that the apparatus itself consists of few parts.

In the train control system the only moving parts are the generator rotor, two switches, and an electro-pneumatic valve controlling the air brake apparatus. No relays or amplifiers are required on the locomotive. The inductors can be placed between the rails or on the outside, and in either case level with the rails. The inductors are not connected with any roadside power. The closed circuit principle, so much desired in safety apparatus, is fully attained. And the combination of these advantages is unique. Furthermore, it is evident that possible uses to which the alternating magnetic Wheatstone bridge may be adapted with advantage are numerous.

Modern Research on Glass.—(T. C. CRAWHALL in *Discovery*, Dec. 1931). In the last few years some research has been conducted for the purpose of throwing further light upon the nature of glass. We are accustomed to look upon this solid as being a supercooled liquid but some modification of these views seem to be in order. It has recently been shown that when glasses are heated or cooled, absorption or evolution of heat takes place at certain points and sharp changes take place in the physical properties of the glass. Such behavior is not typical of supercooled liquids.

As is well known iron is a common impurity in quartz sand and is particularly objectionable when used for glass making. It is iron which produces the green color often seen in common glass. In order that the iron content shall be as low as possible a very pure grade of sand must be chosen, free iron can be removed by passing the sand over magnetic separators, and the color produced in the glass by the remainder may be " neutralized " by the addition of other substances, manganese being commonly used for this purpose.

For window glass a typical formula would be 200 parts by weight of sand, 66 parts of limestone, 59 parts of soda ash and 10 of salt cake. The formula for crystal glass calls for 133 parts of red lead to every 200 parts of sand, 67 of potash and 11 of nitre with a very small amount of nickel oxide (about 0.0003).

There is no doubt but what glass is an extremely durable substance, archeologists will vouch for that. However, to secure this durability the constituents must be correctly proportioned. Manganese, used as a decolorizer, if not added carefully will lead to the development of a purple color after exposure to the atmosphere for some time. This defect often may be observed in old windows.

When glass is drawn out into very fine flexible fibers it is known as glass " wool " or " silk." This glass silk is being used in increasing quantities as an insulating covering for high temperature boilers and steam pipes. It will constantly withstand temperatures up to 900° F. without disintegration. Glass silk also has been used as separator plates for storage batteries. The strength of glass can be increased by toughening the surface through rapid cooling. A piece of this glass 1/4-inch thick 3 feet long and 1 foot wide will carry a weight of more than 280 pounds when supported at its ends and loaded in the centre. The sag at midpoint will be about 2 inches and when the load is removed the glass returns to its normal shape. This type may prove a real rival to the so-called laminated glass so extensively used in automobiles.

T. K. C.

PHOTOGRAPHY OF THE DISTURBANCE WHICH PROPAGATES DETONATION TO A CHARGE OF EXPLOSIVE.[1]

BY

D. B. GAWTHROP.[2]

More knowledge about the mechanism of transfer of detonation from one cartridge of explosive to another when the cartridges are separated, is necessary to explain the distance effects obtained in "gap tests." A cartridge of explosive—the initiator—is exploded by a detonator and a second cartridge of explosive—the receiver—is exploded by the disturbance from the initiator. Both cartridges are wrapped in a confining paper tube and the air column left between the ends of the cartridges is lengthened until detonation of the receiver fails. Measurement of the limiting distance over which detonation of the receiving cartridge occurs is taken as the relative sensitivity of the explosive.

This paper describes experiments in which the receiving cartridge of explosive is photographed by means of the Schlieren method. In this method, wave phenomena and gases are rendered visible by an optical device which depends for its operation upon differences in the index of refraction of the wave or gases and the surrounding atmosphere. Preliminary experiments showed the value of photographic time and distance records obtained with this method and the need for instantaneous snapshot photographs for interpreting such records.

RESULTS OF PREVIOUS INVESTIGATIONS.

Sensitiveness to detonation by influence is an important physical characteristic of explosives and has been studied by a

[1] Published by permission of the Director, U. S. Bureau of Mines. (Not subject to copyright.)

[2] Assistant explosives engineer, U. S. Bureau of Mines, Pittsburgh Experiment Station, Pittsburgh, Pa.

number of investigators.[3] Vieille [4] was the first to show experimentally that a disturbance such as that obtained by firing a detonator would pass through the surrounding atmosphere at velocities higher than that of sound. He measured the velocity of the disturbance in hydrogen, air, and carbon dioxide at reduced, normal, and elevated pressures. He concluded that he was dealing with a propagating phenomenon and not with physically moving gases. Payman [5] took clear spark photographs and moving film records of the wave motion initiated by a detonator, using the Schlieren method of photography. It was shown that the disturbance from a detonator had the characteristics of a discontinuous wave motion of high intensity and that the flame was blanketed by gaseous products of detonation.

Data have been presented, notably by Comey [6] and by Perrott,[7] on the speeds of propagation of detonation between two or more cartridges of explosive in air and in gases such as hydrogen or carbon dioxide. With some types of explosives the speeds of propagation varied inversely with the density of the medium between the charges of explosive, which indicated that the disturbance causing detonation of the receiver was a wave motion.

Olsen [8] has suggested the exposure of explosives to electronic bombardments, believing that by noting the critical velocities of the bombarding electrons a set of indices can be assigned to explosive substances which will serve as a quantitative means of describing their relative sensitivities to detonation.

Moving film photographs which have been taken of the flame from the explosive show the relative time of detonation of the initiator and receiver.[7] The receiver may explode

[3] Berthelot, "Explosives and their Power," p. 75, John Murry, London, 1892. Munroe, *J. Am. Chem. Soc.*, 1893, **15**, 10. Dautriche, *Compt. Rendus*, 1907, **144**, 1030.

[4] Vieille, *Mem. des poud. et Salpetres*, 1899, **10**, 177.

[5] Payman and Robinson, Safety in Mines Research Board Paper No. 18, Great Britain.

[6] Comey, 7th Int. Cong. Appli. Chem., London, 1909, Section III, p. 28.

[7] Perrott and Gawthrop, J. FRANK. INST., 1927, **203**, 387, and J. FRANK. INST., 1929, **208**, 643.

[8] Olsen, Army Ordnance, 1924, **5**, 517.

either before or after the flame from the initiator strikes it. Particularly if the air in the gap between the initiator and receiver is replaced by hydrogen, the receiver often explodes 0.005 second after the flame strikes it. Delayed explosions occur when the gap is near the limit beyond which propagation ceases to take place. From the photographs it seemed probable that there is a critical velocity of a wave motion for each explosive that initiates detonation of the receiver. However, as the length of the gap is increased, the receiver does not always explode when struck by the wave motion, but is set off by a later disturbance, perhaps by the gaseous products of explosion.

Laffitte [9] measured photographically the velocity and length of the flame obtained when a charge of dynamite was fired in a glass tube, and concluded that the wave motion was luminous. In a recent paper by Gawthrop, Shepherd, and Perrott,[10] it was shown by means of Schlieren photography that the disturbance in a cellophane tube from an initiator had the characteristics of a plane wave, moving at a velocity greater than that of the spherical wave sent out by an explosive, and was followed principally by gaseous products of detonation and flame. Initially, there is no distinguishable time interval between the wave and the flame, but the wave does not diminish in velocity as rapidly as the flame. The wave may be photographed after the flame ceases to have any actinic value.

THE SCHLIEREN METHOD OF PHOTOGRAPHY.

The Schlieren method depends for its operation upon the refraction of a beam of light at a surface where there is a distinct change in the density of the atmosphere. A simple theoretical description of it is given in a previous paper in the JOURNAL OF THE FRANKLIN INSTITUTE.[9] Payman [5] describes the method and furnishes a survey of the literature. Only a brief description of it will be given here.

Light from a suitable source is brought to a focus by means of a concave mirror on the surface of a lens mounted in a camera. Half of the lens opening is covered with an opaque

[9] Laffitte, *Ann. des Phys.*, 1925, 4, 587. *Compt. Rendus*, 1924, 176, 1277.

[10] Gawthrop, D. B., Shepherd, W. C. F., and Perrott, G. St. J., J. FRANK. INST., 1931, 211, 67.

diaphragm. Part of the light passes through the lens producing an image of the mirror on a ground glass plate at the back of the camera, but most of the light falls on the diaphragm. An example of a disturbance to be photographed is a sphere of gas, of a density greater than the atmosphere, placed between the mirror and the lens. Rays of light striking the edges of the sphere in a plane parallel to the diaphragm are refracted. Some rays which originally fell on the diaphragm now fall on the lens and others that fell on the lens now fall on the diaphragm. A view of the ground glass plate will show an image of the mirror and an outline of the sphere of gas, half of which is bright and the other half dark, corresponding to whether the refracted light was bent into the lens or onto the diaphragm.

In photographing the disturbance from a charge of explosive, two methods are available. Moving film records give a continuous picture of the relative position of the wave, gases and flame in a time and distance graph. A continuous source of illumination is required, which was furnished by a mirror arc lamp. The photographs were taken with the optical arrangement and apparatus described in the previous article.[10]

Instantaneous snapshot photographs of a wave motion having a velocity greater than the velocity sound in air (330 meters per second) require an exposure of the order of 10^{-6} second to obtain an image of the wave which is not blurred by its movement during the exposure. Also the exposure must be made when the disturbance is in the field of view. These conditions are fulfilled by using a spark discharge as the source of illumination and discharging the spark by the disturbance to be photographed. Cranz and Bames state that the duration of luminosity of a spark is of the order of 10^{-7} second. Even with this extremely short exposure the spark is sufficiently actinic to affect the photographic film satisfactorily.

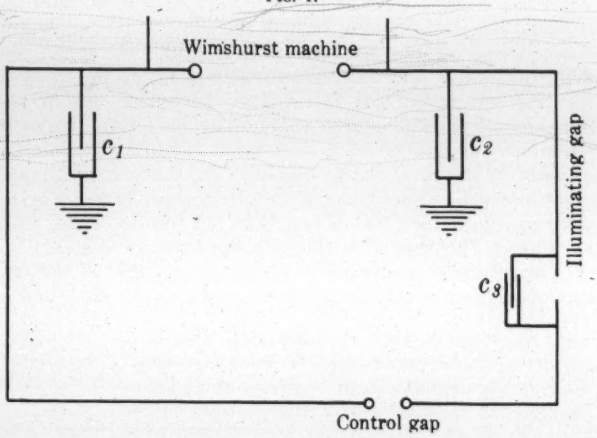
ELECTRICAL APPARATUS.

An electrical arrangement supplying a spark for illuminating purposes and a method of timing the exposure when the disturbance is in the field of view, is given by Layman [6] and by Smith.[11] A diagram of the circuit is shown in Fig. 1.

[11] Smith, *Physical Review*, 1925, **25**, 870.

A Wimshurst static machine charges two condencers C_1 and C_2 having a total capacity of about 0.04 microfarad. Two spark gaps, the illuminating gap and control gap, are connected in series with the static machine. The control gap is closed by placing it in the path of the gaseous products from the explosive charge, which are sufficient to break down the

FIG. 1.



Detail of illuminating gap

Diagram of electrical apparatus.

air insulation normally in the gap. The illuminating spark can be made to pass at any desired time by moving the gap to different positions with respect to the charge of explosive.

The illuminating spark passes between the ends of magnesium rods which are inserted in a special capillary tube. A detail drawing of the tube is included in Fig. 1. A capacity of 0.004 microfarad is connected in parallel with the spark

gap to increase the luminosity of the spark. The control gap consists of two steel balls 1 centimeter in diameter, mounted in the conventional manner.

EXPERIMENTAL PROCEDURE.

In the following experiments carried out to study the transfer of detonation from one charge of explosive to another when the charges were at opposite ends of a tube, only the receiver was in the field of view of the camera. The initiator was screened off from the receiver to eliminate the spherically expanding wave and gaseous products from interfering with the photography of the disturbance advancing within and immediately outside of the tube. The initiating charge of permissible explosive was so selected as to obtain a minimum of flame in the tube and to transfer detonation over a maximum distance. The composition of the receiver was varied, since previous work has shown that the results of gap tests are affected the most with different explosives as receivers.

The chemical analysis and physical constants of the two explosives used in taking the photographs shown are given in Table 1.

TABLE 1.

Properties of Explosives Used in Experiments.

Name.	Chemical Analysis, Per Cent.								Apparent Density, Grams per c.c.	Rate of Detonation, Meters per Second.*	Sensitiveness to Detonation, Cm.*
	Moisture.	Nitroglycerine and Nitroglycol.	Nitrocellulose.	Ammonium Nitrate.	Sodium Nitrate.	Sodium Chloride.	Calcium Carbonate.	Carbonaceous and Combustible Material.			
Permissible type....	0.4	17.9	0.2	60.9	9.0	5.1	1.1	5.4	1.12	4320	60
40 per cent. dynamite.....	0.9	39.5			44.2		0.9	14.5	1.35	4860	100

* Determined with 3.2 × 20.3 cm. commercial cartridges of explosive.

THE DISTURBANCE WHICH PROPAGATES DETONATION.

The disturbance from a charge of explosive fired at one end of a cellophane tube has been photographed on a moving film by means of the Schlieren method and described in a previous

paper.[10] The addition in this paper of instantaneous Schlieren photographs of the disturbance, presents further information pertaining to the nature of the disturbance and the effect on the cellophane tube. The photographs will now be described.

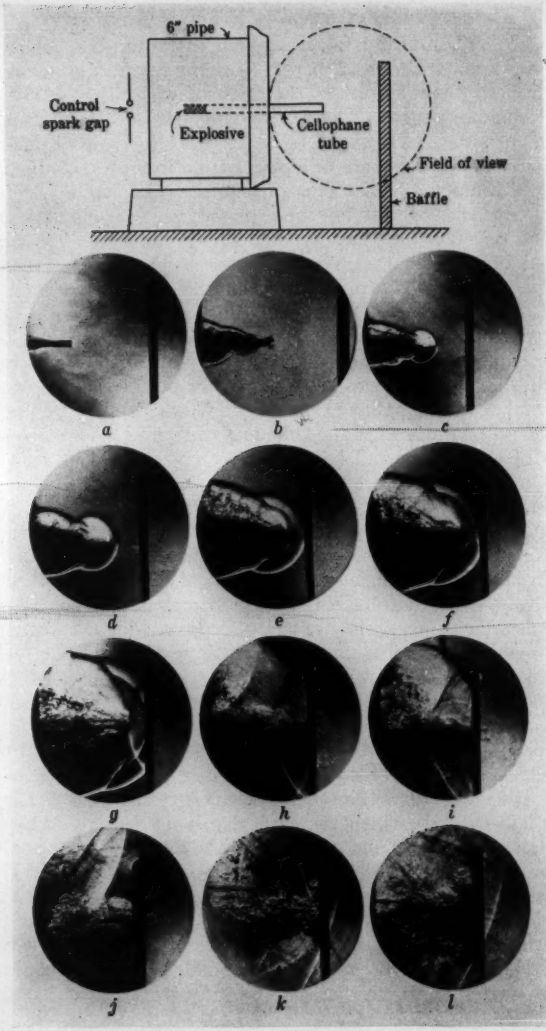
Figure 2. A charge of permissible explosive was packed into one end of a square cellophane tube to form a charge 1.3 cm. in diameter and 5 cm. in length. The No. 6 electric detonator employed to fire the explosive was placed in the end of the tube and the explosive packed around it. The total length of the tube was 23 cm. A short length of pipe 6 inches in diameter, with a cap screwed on the end of it, served to screen the charge of explosive. The cellophane tube projected 10 cm. out through a hole drilled in the center of the pipe cap, leaving the explosive inside the pipe. A wooden baffle 20.0 cm. wide was placed at a distance of 10.0 cm. from the end of the cellophane tube. The photographs were taken of the projecting end of the tube and the baffle. The disposition of the charge and baffle relative to the field of view is shown in the figure.

A series of spark Schlieren photographs is shown of the phenomena initiated by the discharge of the explosive as they passed across the field of view of the camera. Each picture is the result of firing single shots of identical charges of explosive and timing the illuminating spark to pass at increasing intervals after the explosive detonated. Increasing the distance between the explosive and the control spark gap effectively timed the exposure with respect to the discharge of the explosive.

In the photograph *a*, a conical wave will be seen outside of the cellophane tube which resembles the waves produced by bullets in flight.[12] This wave is initiated by the passage of a plane shock wave within the tube. The shock wave is initiated in the tube when the explosive is fired. It is discontinuous in character and advances in the air inside of the tube ahead of any forward movement of gases liberated by the explosive. Gases closely following the plane wave break the tube at irregular points, which causes the formation of spherically expanding waves along the surface of the tube. These later waves obscure all but a small part of the conical

[12] Quayle, JOUR. FRANK. INST., 1922, 193, 627.

FIG. 2.


6" pipe
Control spark gap
Explosive
Cellophane tube
Field of view
Baffle
a
b
c
d
e
f
g
h
i
j
k
l

wave. In *b*, the plane wave is seen emerging from the mouth of the tube where it expands spherically. The conical wave is visible over a short length of the tube, but the remainder of the wave is covered by the waves expanding from the surface of the tube. The tube has broken sufficiently to allow gases to expand around it.

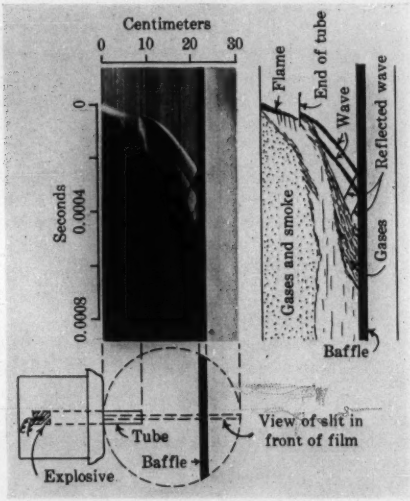
c and *d* show further expansion of waves from the end and surface of the tube. Gases are emerging from the end of the tube preceded by a second spherical wave. Pieces of cellophane tube are shown and a few particles may be seen breaking through the front of the wave at its nose. In *e*, the wave has reached the baffle. The head of a column of gases is clearly distinguishable. A weak flame is shown at the back of the tube; *f* shows the wave reflecting from the baffle, advancing gases, and many fine particles striking the baffle; *g* and *h* show the gases passing through the reflected wave and a reversal in the direction of expansion of a part of the reflected wave. In *h* the wave is seen passing over the end of the baffle. The origin of the wave advancing from the upper left side of the field of view is not clear. Two small holes punched through the baffle, presumably by pieces of copper from the detonator, allow a small portion of the wave and later gases to go through the baffle. In *g* this wave reproduction is faint and in *h* the gases are through the baffle. In *i* the head of the gas column has reached the baffle, and in *j* the gases are shown mushrooming against the baffle; *k* and *l* show the gases piling up against the baffle and particularly in *k* the pieces of the cellophane tube are very evident.

Figure 3. A similar arrangement of explosive in a cellophane tube to that shown in Fig. 2 was photographed on a moving film. An explanatory diagram of the photograph is given in Fig. 3. Movement of phenomena in a direction parallel to the slit in front of the film is recorded. Waves and gases advancing from the open end of the tube are photographed but none of the components of motion at right angles to the slit. Velocity measurements from Fig. 3 indicate the relative positions with respect to time, of the phenomena shown in Fig. 2.

The average velocity of the wave between the end of the tube and the baffle was 710 meters per second, and that of the

second wave 530 meters per second. Gases projected from the tube mouth advanced at an average velocity of 290 meters per second and struck the baffle 0.00024 second after the arrival of the first wave at the baffle. These gases are separated from the main body of gaseous products of detonation by about 0.002 second.

FIG. 3.



TRANSFER OF DETONATION TO 40 PER CENT. DYNAMITE.

The foregoing gives a comprehensive picture of the disturbance emerging from the end of a cellophane tube when a charge of permissible explosive was fired at the opposite end of the tube. A series of photographs will next be shown in which a charge of explosive was packed in each end of the tube and the photographs taken of the receiver in the tube. The disposition of the initiator and cellophane tube relative to the field of view was the same as that shown in Fig. 2. The distance between the charges of explosive was adjusted to

insure at will either failure or certainty of detonation of the receiver.

Figure 4. The initiator consisted of a charge of permissible explosive identical with the charge employed in taking the photographs shown in Fig. 2 and the receiver a charge of 40 per cent. straight dynamite measuring 2.5 cm. in length. Adjacent ends of the initiator and receiver were separated a distance of 43 cm., at which distance detonation was not transferred to the receiver. In *a* the plane wave advancing within the tube may be seen as a straight line across the tube where the conical wave touches the outside surface of the tube; *b* and *c* include in the field of view, the waves produced at the surface of the tube and the leakage of gases from the tube. The conical wave is shown further advanced along the tube. In *d* the conical wave has arrived at the receiver and maintains its position ahead of the remainder of the disturbance. The tube has noticeably expanded in diameter with considerable leakage of gases surrounding it. In *e* the wave motion has almost passed around the receiver. The tube is distorted and appears to be broken. The receiver has moved a slight distance away from the initiator and the gases are seen surrounding it.

Figure 5. In this series of photographs detonation was transferred to the receiver. The distance between the initiator and receiver was reduced to 30.5 cm. The flame produced by the detonation of the receiver registers on the film due to its actinic value and photographs irrespective of the timing of the spark illumination. Hence, there are usually two exposures for each view, one of the wave phenomena and one of the flame, since the shutter of the camera remains open during the entire procedure.

In *a* the conical wave is shown before it reaches the receiver. Since the wave is the first disturbance arriving at the receiver, the explosive had not fired at the time the wave record registered on the film. The flame from the initiator is visible in the tube due to the decreased distance between the initiator and receiver. In *b* the wave is shown approximately at the time of its arrival at the receiver. The exact time of arrival of the wave is difficult to determine on account of the superimposed flame record. *c* shows the wave initiated by

FIG. 4.

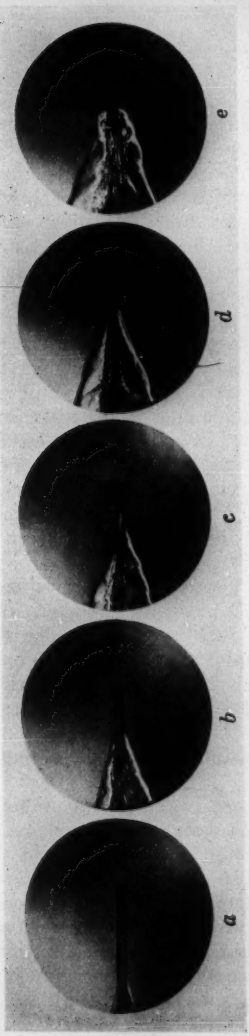
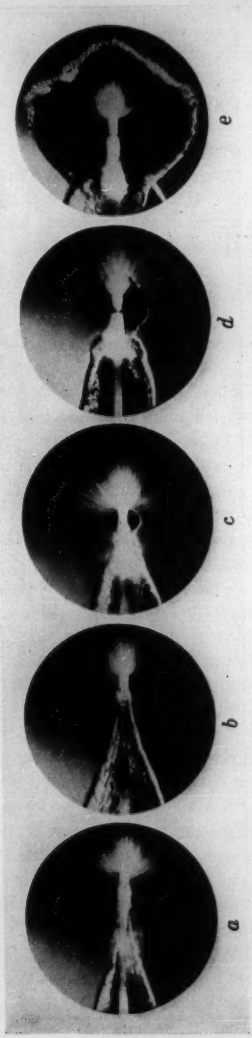


FIG. 5.



the receiver with the center of the disturbance at the end of the receiver nearest the initiator. From the relative positions of the waves, detonation of the receiver must have occurred about the time the plane wave in the tube struck the receiver, or very shortly afterward. Further spherical expansion of the wave initiated by the receiver is shown in *d*, which indicates conclusions similar to those arrived at in *c*. *e* is shown primarily for the shape of the wave produced by the receiver. A large number of flying particles are produced which came from the explosive and its wrapper and are not pieces of copper from the detonator.

FIG. 6.

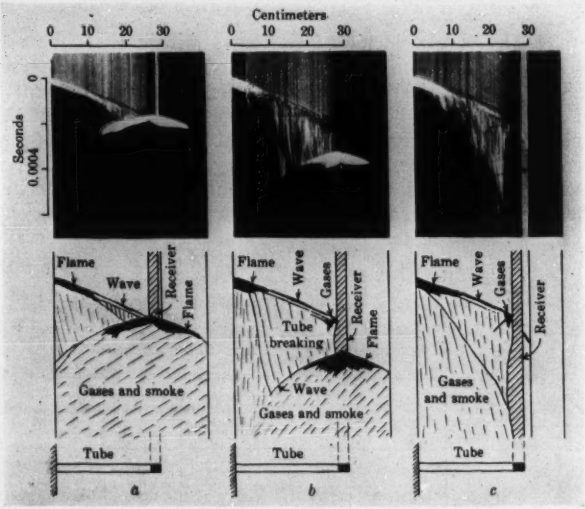


Figure 6. The effect of the disturbance on the receiver was also photographed on a moving film. The time of detonation of the receiver relative to the disturbance propagated by the initiator is definitely shown.

In *a* and *b* the length of the air column between the initiator and receiver was 38.1 cm. *a* shows the 40 per cent. straight

dynamite receiver exploding when the shock wave within the tube struck it. In *b* the receiver did not detonate until 1.4 milli-seconds after having been struck by the shock wave. Here the gases moving through the tube piled up against the receiver causing the end to be deformed before the explosive detonated. This type of delayed detonation occurs frequently when the distance between the initiator and receiver is near the limiting distance for the transfer of detonation. In *c* the receiver failed to detonate entirely. The length of the air column between the initiator and receiver was 40.7 cm., an increase of 2.6 cm. over the length in *a* and *b*. The velocity of the wave and gases was slightly less in this case and of not a sufficient intensity to transfer detonation to the receiver.

The average velocity of the wave within the tube was measured from photographs over a distance of 10 cm. before the wave struck the receiver. The effect of varying the length of the air column between the charges of explosives on the velocity of the wave is given in Table 2. From the data presented, an average wave velocity of 1,430 meters per second is required to transfer detonation to the receiver. Delayed detonations were obtained when the wave velocity averaged 1,330 meters per second and with an average wave velocity of 1,190 meters per second or less, the receiver fails to detonate.

TABLE 2.

Distance Over Which Detonation Is Propagated in Cellophane Tubes to a Charge of 40 Per Cent. Straight Dynamite from a Charge of Permissible Explosive.

Length of Air Column, Cm.	Velocity of the Wave, Meters per Second.	Effect on the Receiver.	Length of Air Column, Cm.	Velocity of the Wave, Meters per Second.	Effect on the Receiver.
38.1	1470	Explosion	43.2	1110	No explosion
38.1	1410	"	43.2	1060	" "
38.1	1370	Delayed explosion	43.2	1420	Explosion
40.7	1310	No explosion	45.7	1030	No explosion
40.7	1150	" "	45.7	1100	" "
40.7	1290	Delayed explosion	45.7	980	" "

Average minimum velocity of the wave to produce explosion, 1,430 meters per second.

Average maximum velocity of the wave which fails to explode the receiver, 1,190 meters per second.

Average velocity of the wave with a delayed explosion, 1,330 meters per second.

The results given in Table 2 are typical for the average "gap test" in which the receiver detonated in three trials over a length of gap of 38.1 cm., and failed to detonate over a length of gap of 45.7 cm. Two intermediate lengths of gap each produced one detonation in three trials. The velocity of the wave in one of the trials of each intermediate length of gap was of sufficient magnitude to produce either an immediate detonation or a delayed detonation of the receiver. In the trials where the receiver failed to detonate, the velocity of the wave was lower than that required to propagate detonation.

TRANSFER OF DETONATION TO A PERMISSIBLE EXPLOSIVE.

Instantaneous and moving film photographs were taken of the transfer of detonation in cellophane tubes to a permissible explosive in place of the 40 per cent. dynamite previously shown. These photographs differ from those of a 40 per cent. dynamite receiver in that the distance between the initiator and receiver is necessarily less to obtain a transfer of detonation to the relatively insensitive permissible explosive.

FIG. 7.

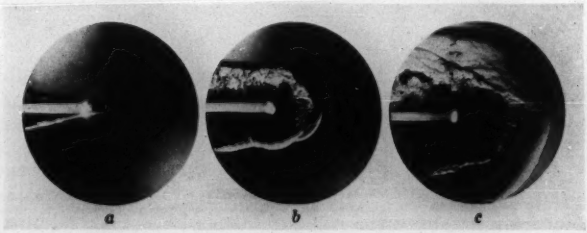


Figure 7. The receiver of permissible explosive measuring 2.5 cm. in length failed to detonate when placed at a distance of 17.8 cm. from the initiator. In this group of photographs, flame from the permissible explosive initiator may be seen in the cellophane tube. When it strikes the end of the receiver the luminosity is increased. In *a* the conical wave is shown at about the time it reached the receiver. In *b* the plane wave produced in the cellophane tube by the initiator has passed

around the receiver and is shown expanding spherically. The gases formerly contained in the tube follow the wave and, finally, gaseous products of explosion which are opaque to the light from the illuminating spark. The waves and gas leakage from the walls of the tube are the same as that indicated with a receiver of 40 per cent. dynamite. The forward movement of the shock wave, gases, and other products of detonation, after passage around the receiver is shown in *c*. Solid particles break through the nose of the wave. Gases from the tube are ahead of the opaque products of detonation and waves are no longer initiated along the surface of the cellophane tube.

FIG. 8.

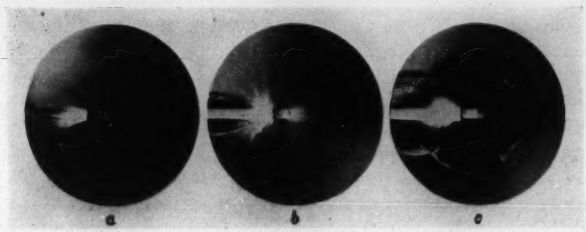
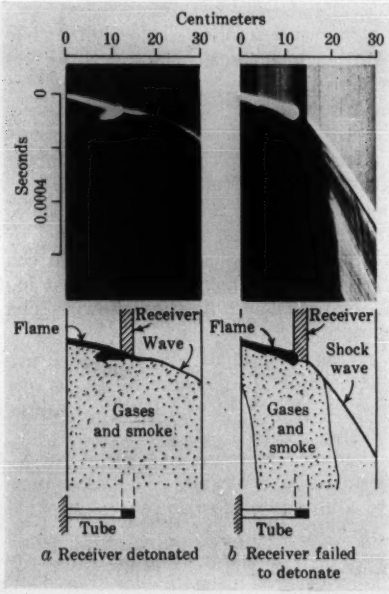


Figure 8. With the length of the air column between the initiator and receiving charges of permissible explosive reduced to 15.2 cm., detonation was transferred to the receiver. Here, as before, with 40 per cent. dynamite the flame from the receiver obscures the view of the disturbance from the initiator. *a* and *b* show different positions of the conical wave before detonation of the receiver takes place. The addition of the flame from the receiver to that in the cellophane tube causes a large flame to be produced at the end of the receiver nearest the initiator. *c* is a photograph taken after the receiver detonated, which shows the wave and gaseous products of detonation from the receiver. The shock wave from the initiator such as is shown in Fig. 7*c* has entirely disappeared.

Figure 9. Moving film photographs of the disturbance from an initiator in a cellophane tube striking a receiver of permissible explosive, are principally time and distance

records of flame. There is no distinguishable difference between the velocity of the flame and that of the shock wave within the tube at short distances from the initiator. In *a* the receiver detonated at the time of arrival of the flame and in turn initiated a relatively weak shock wave of its own. In *b* the flame struck the receiver, and the wave passing

FIG. 9.



a Receiver detonated *b* Receiver failed to detonate

around it expanded spherically at a lower velocity. The average velocity of the flame striking the receiver in *a* was 2,370 meters per second and in *b* 2,380 meters per second. The average velocity of the wave initiated by the receiver over the distance photographed in *a* was 1,450 meters per second and that of the wave passing around the receiver in *b* 470 meters per second.

CONCLUSIONS.

The following conclusions may be drawn from a study of the photographs and the data presented:

1. The disturbance produced by firing a charge of permissible explosive in one end of a cellophane tube consists of the following:

(*a*) A plane discontinuous wave is sent through the air in the tube, accompanied by a conical wave surrounding the tube.

(*b*) The plane wave is followed closely by gases within the cellophane tube which break through at irregular points along its surface.

(*c*) Spherical expanding waves are produced along the outer surface of the cellophane tube where it is ruptured.

(*d*) The principal part of the gaseous products of explosion follow after the cellophane tube is broken up.

2. A sensitive receiving cartridge of explosive, such as 40 per cent. straight dynamite, may be exploded by the plane wave sent through a cellophane tube. With charges of explosive of the physical dimensions employed in taking the Schlieren photographs shown, the following characteristics of the wave apply:

(*a*) The average minimum velocity of the wave required to transfer detonation to a charge of 40 per cent. straight dynamite from a charge of permissible explosive is 1,430 meters per second.

(*b*) The average maximum velocity of the wave from a charge of permissible explosive which does not propagate detonation to a charge of 40 per cent. straight dynamite is 1,190 meters per second.

(*c*) Detonation of a charge of 40 per cent. straight dynamite occasionally occured after the plane wave struck it. In this case the velocity of the wave was found to be between 1,440 and 1,190 meters per second, and the delay in detonation of the order of 1.4 milliseconds.

3. Detonation is transferred to a cartridge of relatively insensitive permissible explosive by physically moving phenomena such as the flame and gaseous products of detonation from the initiator.

(*a*) No appreciable difference exists between the velocity of the wave in the tube and the flame from the initiator over the distance necessary for the transfer of detonation to a permissible explosive.

(*b*) Under the conditions of these experiments, it was found that a charge of permissible explosive detonated, or failed to detonate when struck by shock waves having the same velocity.

DISCUSSION.

The gases following the shock wave such as were photographed emerging from the open end of a cellophane tube are factors which aid in the transfer of a delayed detonation to the receiving cartridge of explosive. They are sent through the tube for a limited time which ends with the breaking up of the cellophane tube. Photographs showed that the receiver did not explode when struck by the shock wave but detonated after gases had accumulated at its face and disturbed the end of the cartridge. Gaseous products of detonation from the initiator expanding spherically outside of the tube, were screened off from the receiver and did not reach it in time to affect its detonation.

In general, the success or failure of propagated detonation to a sensitive charge of explosive depends upon the total energy of the blow struck by the disturbance from the initiator. A measure of the energy in the shock wave is its speed, and a decrease in energy is apparent in the lower velocity of the wave. There is a critical velocity of the shock wave which always propagates detonation to a sensitive receiver, and similarly, there is a lower velocity of the shock wave which does not transfer detonation. However, shock waves having an intermediate velocity with the help of the gases sent through the cellophane tube sometimes produce delayed explosions of the receiver. In this way the energy of the blow struck is built up until the receiver detonates.

Considerable spread is usually experienced between the distance at which detonation is always propagated from one cartridge of explosive to another, and the distance at which the transfer of detonation never occurs. With sensitive explosives this spread may be attributed to differences in the sensitivity of the individual cartridges of explosive to the

blow struck, or to differences in the initial velocity of the shock wave. Particularly in this investigation, where the explosives were repacked in cartridges of small diameter, variations in the packing density affected the sensitivity and velocity of the wave from the explosive.

In the transfer of detonation to an insensitive cartridge of permissible explosive, the flame and reacting gases from the initiator which strikes the receiver are important factors in the processes. Data were presented in a previous paper [5] which indicated that the reaction of the gaseous products of explosion with oxygen increases the distance over which detonation is propagated to a permissible explosive. There were no appreciable differences in the velocity of the shock wave within the cellophane tube for either success or failure in transferring detonation to the receiver.

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EVIDENCE FOR THE EXISTENCE OF THE ETHER.*

BY

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An impression prevails in these days that the ether postulated by Newton, Faraday, Kelvin, Maxwell and Lorentz is a figment of the imagination—that the theory of relativity through its prophets Einstein, Eddington, Jeans and others has shown it to be non-existent and its assumption an anachronism. This impression is a mistaken one, for it can easily be shown that Faraday himself was no more insistent that the ether exists than Eddington and Einstein. Thus Eddington says:

> "The most formidable objection to this relativist view of the world is the ether difficulty. . . . Some would cut the knot by denying the ether altogether. We do not consider that desirable, or so far as we can see, possible." [1]

And Einstein confirms him in the following declaration:

> "According to the general theory of relativity space without ether is unthinkable; for in such space there not only would be no propagation of light, but also no possibility of existence for standards of space and time (measuring-rods and clocks), nor therefore any space-time in the physical sense." [2]

Despite these authorities to the contrary, however, there is no doubt that most relativists are strongly inclined to deny the existence of the ether. Now why do they deny it? Evidently because it is not observable. No one has ever seen it with his eyes or touched it with his hands; and how can anything which exists all around us and even within our bodies, be neither visible nor tangible? If it is so near us why do we not perceive it? Such an argument appeals to the reason of all of us. Nevertheless, if we reflect a little we may decide

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* Presented at meeting held Thursday, January 14, 1932.

[1] Eddington, A. S., "Space Time and Gravitation," pp. 38, 39.

[2] Einstein, A., "Sidelights on Relativity," p. 23.

that its cogency is debatable. A blind man cannot see the material things which surround him, and paralysis of the sensory nerves of the body's surface would deprive him of the sense of touch so that he could not feel them. Yet material things would certainly continue to surround him. They would not cease to be existences because of the limitation of his senses. And shall we maintain that sight and touch are the only means of perceiving external existences? They are the only human means perhaps, but can we insist that human powers of perception shall be the tests of what exists in space? That man's limitations are necessarily nature's? Not if we are reasonable. More and more as our knowledge advances we discover that, despite the contention of Protagoras, man is not the measure of all things.

That we cannot see or touch the ether does not show that it does not exist. It only shows that human beings are not beings qualified to observe it. But man has a subtler sense than sight or touch. It is what the ancients called the inner or interior sense, the sense by which he infers, the sense through which it may perhaps be revealed that the intangible is a far more important part of the universe than the tangible, the unseen than the seen. It is by the interior sense that we discover the ether. We cannot perceive it, but through perception it can be inferred. And the evidence at present available indicates that the material universe compared to the non-material is insignificant, as much so as the universe of Ptolemy was insignificant compared to the universe of Copernicus. Contrary to the opinion of the ancients the earth is a mere particle of dust compared to the total matter of the cosmos, and contrary to the opinion of most relativists, the totality of matter of the cosmos is probably a mere scattering of such dust compared to the medium in which it floats, a medium unseen by eyes and unfelt by hands.

We of this age should have little difficulty in crediting the existence of the ether. For we live in a world crowded by numberless radio programs, which not only pervade the atmosphere, but the houses in which we live and the bodies through which we feel. Yet unless provided with a special receiving organ by which to detect them we are unconscious of their existence. If this is the case why should it be so

difficult to believe that an ether exists all around us of whose presence we are similarly unconscious because we are unprovided with receiving organs by which to detect it. Long before the days of radio Huxley had sensed the limitations of man's perceiving organs, and expressed himself in the following suggestive passage:

"The ultimate forms of existence . . . in our little speck of the universe are, possibly, . . . of infinite varieties . . . in the midst of which, indeed, we might be set down, with no more notion of what was about us, than the worm in a flower-pot, on a London balcony, has of the life of the great city."[3]

Such a surmise has far greater probability to-day than in Huxley's time; the theory of Protagoras is more obsolete than in any previous age. Thus it is not the notion of an ether that is an anachronism. The anachronism is the notion that because we cannot perceive the ether it does not exist.

All this of course is a mere negative argument for the ether. We are simply pointing out that man's failure to perceive the ether affords no considerable presumption of its non-existence. But the absence of presumption of non-existence is no proof of existence. For such proof evidence much more positive is required and to evidence thus positive we now may turn.

Tolman, voicing the usual view of the relativists that there is no ether, expresses himself as follows:

"There is nothing out in space in the nature of an ether or of a fixed set of coördinates with regard to which motion can be measured."[4]

He also expresses what he calls the first postulate of relativity, which follows from this assumption, thus:

"The first postulate of relativity as originally stated by Newton was that it was impossible to measure or detect absolute translatory motion through space. . . . In the development of the theory of relativity, the postulate has been modified to include the impossibility of detecting translatory motion through any medium which might be assumed to pervade space."[5]

In the present lecture I propose to present evidence that this first postulate of relativity, on which the theory of relativity rests, is mistaken—that it applies to a single special

[3] Huxley, T. H., "Essay on Hume," p. 286.
[4] Tolman, R. C., "The Theory of the Relativity of Motion," p. 18.
[5] *Ibid.*, p. 20.

case only—that of uniform motion in a straight line. And the failure to detect this is doubtless due to compensating effects. All other kinds of absolute motion, both rotary and translatory, are easily detectable. And by absolute motion I mean what the relativists mean, namely, motion relative to an absolute frame of reference or ether, pervading space and matter. The fact is that few things in external nature are easier to detect than absolute motion. Let us examine the evidence for this statement; not all of the evidence, but merely that easily obtainable from inertial phenomena.

It will be noted that Tolman specifies "translatory" motion as the kind that cannot be absolute. He does not deny that rotary motion can be. Indeed the existence of absolute rotary motion is generally admitted by the relativists. Einstein, for instance, is quite explicit in maintaining it, as in the following passage:

"To deny the ether is ultimately to assume that empty space has no physical qualities whatever. The fundamental facts of mechanics do not harmonize with this view. For the mechanical behaviour of a corporeal system hovering freely in empty space depends not only on relative positions (distances) and relative velocities, but also on its state of rotation, which physically may be taken as a characteristic not appertaining to the system in itself. In order to be able to look upon the rotation of the system, at least formally, as something real, Newton objectivises space. Since he classes his absolute space together with real things, for him rotation relative to an absolute space is also something real. Newton might no less well have called his absolute space 'Ether'; what is essential is merely that besides observable objects, another thing, which is not perceptible, must be looked upon as real, to enable acceleration or rotation to be looked upon as something real.

"It is true that Mach tried to avoid having to accept as real something which is not observable by endeavouring to substitute in mechanics a mean acceleration with reference to the totality of masses in the universe in place of an acceleration with reference to absolute space. But inertial resistance opposed to relative acceleration of distant masses presupposes action at a distance; and as the modern physicist does not believe that he may accept this action at a distance, he comes back once more, if he follows Mach, to the ether, which has to serve as medium for the effects of inertia."[6]

Thus Einstein plainly perceives that Mach's "totality of masses in the universe" theory of inertia involves the existence of an ether or absolute frame of reference, and accepts Mach's theory only with that understanding. Moreover, he

[6] Einstein, A., "Sidelights on Relativity," pp. 16–18.

distinctly affirms the existence of rotary motion relative to that ether. Yet if he affirms absolute rotary motion, how can he deny absolute translatory motion? If it be admitted that there is an absolute frame of reference in space to which rotary motion can be relative, how is it that translatory motion relative to that frame becomes impossible? Can anything in space be mentioned, or even imagined, relative to which rotary motion is possible, but translatory impossible? If so, what is it? Surely the existence of such a thing is even more difficult to admit than of an ether. The earth, for instance, is in rotary motion relative to the ether, and Einstein agrees that it is. If so, how can a point on its equator fail to be in translatory motion relative to the same ether? A Hindoo mystic might perhaps explain such a contradiction to the satisfaction of other mystics, but can a physicist explain it to the satisfaction of other physicists?

We shall see presently that the one kind of motion is as easily detected as the other. But first let us point out how easy it is to prove absolute rotary motion. Newton proved it with a bucket of water, and I am not aware that anyone has ever questioned his proof. Suppose we describe his experiment; but to make the proof a little clearer, let us use two buckets instead of one, each about half full of water. One of these we place on any convenient support some distance above the floor, say on a shelf attached to the wall of a room and through the wall to the earth. This bucket is attached firmly to the shelf, say by a few screws, and is called the grounded bucket. The second bucket is suspended from the first at the center of its bottom by a piece of rope, say eight feet long, the rope passing through a hole in the shelf. This bucket thus hangs freely, its axis coinciding with that of the grounded bucket. We may call it the suspended bucket. We now twist the suspended bucket around its axis till the rope is well twisted. On releasing it, the rope untwists, rapidly rotating the bucket, and anyone who cares to may observe that, during the rotation, the surface of the water becomes concave, rising higher around the circumference than at the center, and the faster the rotation the more concave it becomes. But if he observes the bucket on the shelf he will notice no

concavity of the water surface. It remains everywhere level. What is the explanation of this unsymmetrical behavior of the two surfaces? Why do they react so differently? You reply no doubt that it is because the behavior of the two buckets is different. One is rotating and the other is not and this is obviously the explanation of the lack of symmetry. There is therefore no puzzle about it. But stop a moment and consider. All motion, including rotary motion, is relative. There is no such thing as non-relative motion. All physicists, relativists as well as non-relativists, agree about this. Even so-called absolute motion is merely motion *relative* to the ether. Hence when we say the suspended bucket is rotating, we should inquire "Relative to what?" To the grounded bucket? Yes, that is true. But it is equally true, since all motion is relative, that the grounded bucket is rotating relative to the suspended bucket, and at the same velocity, though in the opposite direction. Bucket A cannot rotate relative to bucket B unless bucket B rotates relative to bucket A. It is impossible. The difference in the behavior of the water surface then cannot be due to the *relative, mutual* rotation of the buckets, since that is the same for both, and as like causes produce like effects, the effect on the water surface should be the same in both cases. If one surface becomes concave the other should also. But it is *not* the same. One surface becomes concave and the other does not. Yet it is evident that the concavity of the water surface in the suspended bucket is caused by its rotation, since when unrotated it remains level. Obviously, then, it must be rotating relative to *something* to which the grounded bucket is not rotating, and something capable of causing physical effects, effects not confined to the surface merely but extending throughout the mass of the water. For the concavity of the surface results from a rearrangement of the particles of the water beneath it. And what can that something be? There is only one answer. It must be to some third frame of reference which is invisible to us, but which not only pervades space, but the water itself. The water can detect this third frame if our eyes cannot. But our eyes can observe the behavior of the water, and from that infer the existence of the third frame which causes it. This third frame may be called the ether. Thus the experi-

ment with Newton's bucket proves the existence of absolute rotary motion, just as Newton claimed it did. Nor has any physicist since his time denied it.

Perhaps, however, we are overlooking something. The suspended bucket rotates relative to the earth, or a horizontal straight line fixed in it, while the grounded bucket does not. Perhaps the earth exerts some mysterious unsuspected inertial influence, as well as the familiar gravitational one, and hence rotation relative to it causes centrifugal force whereas rotation not relative to it does not. This is a natural assumption, since our habits cause us to regard all motion as relative to the earth. We unconsciously assume it as an absolute frame of reference. The relativists themselves are constantly doing it, and we shall presently cite a concrete example of this from the writings of Eddington. Such an assumption, however, is erroneous. The earth is no more an absolute frame of reference than any other body—the sun, the moon, or the suspended bucket. Its mere presence can exert no inertial effect on the rotating water. Hence the difference in the rotation of the two buckets relative to the earth, or a straight line fixed in it, is merely incidental, and cannot be the cause of the difference in the shape of the water surfaces. The only influence of the earth is gravitational. It tends to hold the water down. It cannot make it rise at the circumference as it is observed to do. The relativists would be the last to consciously claim the earth as an absolute frame of reference merely because it is the one from which human observers make their observations. As Eddington says:

> "Once he [an observer] gives up the naïve assumption that his own frame is the one and only right frame the question arises, Which then of the innumerable other frames is right? There is no answer, and so far as we can see no possibility of an answer."[7]

That is to say, the relativists deny that any frame of reference is absolute. Hence they deny that the earth is.

That the earth is not an absolute frame is shown best perhaps by tidal phenomena. The moon causes, not one, but two tides in the oceans of the earth, one gravitational, the other inertial. On the side next the moon the water is raised

[7] Eddington, A. S., "The Nature of the Physical World," p. 15.

away from the earth and toward the moon. On the side away from the moon the water is raised away from both the earth *and* the moon. This is the inertial tide. What causes the water to rise against the force of gravity of both bodies? The cause is the same as that which causes the water at the circumference of Newton's bucket to rise. Whenever the motion of a body is deviated from a straight line this force arises. It is called centrifugal force. It is the force which causes the inertial tide. And it is caused by the deviation of the motion of the *earth itself* from a straight line, a deviation caused in turn by the gravitation of the moon, which forces the earth to revolve around the common center of gravity of the two bodies. But straightness and curvature are as much relative as motion. A point on the circumference of a moving automobile wheel moves, relative to the hub, in a circle, but relative to the road it moves in a cycloid. Viewed from the pole of the ecliptic the earth moves in an ellipse. Viewed from the equator thereof it moves in a straight line. From what straight line then is the motion of the earth deviated by the moon? It cannot be any straight line fixed in the earth itself, since from such a straight line there could be no deviation because the line would move with the earth. Fixed in what then? There is but one answer. In the ether. Absolute rotation is a deviation from a straight line so fixed, and it is the cause which produces both the concavity of the water in Newton's bucket and the inertial tide on the earth. In each case the water knows when it is deviated from such a line and gives notice of the fact. The earth's presence has no more inertial influence than that of a toy globe. Thus the argument from Newton's bucket is reinforced by that from the earth's inertial tide. Absolute rotary motion is easily detected, and even the relativists do not deny this.

Now it may be readily shown that absolute translatory motion is no less easy of detection. Moreover, no new principles of mechanics and very little new apparatus is required to prove it. We have only to vary the experiment of the two buckets a little and use the same reasoning as before. Suppose we attach the grounded bucket to the floor or to any rather heavy body in any manner we please. Screwing it to a heavy door laid flat on the ground will do. Leaving the

water in the buckets we now pick up the suspended bucket by its rope and, holding it steadily, we walk toward the grounded bucket attached to the door, so directing it that after a few paces, during which its motion is kept uniform, it collides with the grounded bucket. As a result of the experiment it is easy to observe the following three facts: (1) The water in the suspended (carried) bucket remains level during its uniform horizontal motion. (2) Immediately after its impact with the grounded bucket it no longer remains level, but surges or splashes, and if our pace is fast enough it may spill over. (3) The water in the grounded bucket remains level both before and after the impact, though it may show slight surface waves immediately following impact caused by the lack of rigidity of the apparatus. These phenomena may be observed by anyone. Here there is no rotary motion, but only translatory motion in a horizontal direction. Yet the same unequal effects are observed. On impact the water in the grounded bucket remains level, but that in the carried bucket does not. What is the explanation of this unsymmetrical behavior? Again you may say it is due to the difference in motion of the two buckets. One is suddenly stopped by the impact while the other is not. And this is obviously the explanation of the lack of symmetry. There is surely no puzzle where the explanation is so simple. But stop a moment once more and consider. All motion, including translatory motion, is relative. Hence when we say the carried bucket is suddenly stopped, we must inquire, "Relative to what?" To the grounded bucket? Yes, that is true. But it is equally true, since all motion is relative, that the grounded bucket is suddenly stopped relative to the suspended bucket, and with the same suddenness, though the retardation (negative acceleration) is in the opposite direction. Bucket A cannot be retarded relative to bucket B unless bucket B is retarded relative to bucket A. It is impossible. The difference in the behavior of the water surfaces then cannot be due to the *relative, mutual* retardation of the buckets, as the relativists maintain, since like causes produce like effects, and the retardation is the same in both cases. Hence the effect of the retardation should be the same in both cases. If one splashes the other should also. But the effect is ***not*** the same. One

surface departs from its level condition and the other does not. Yet it is evident that the splashing in the suspended bucket is caused by the impact with the grounded bucket, since when moving uniformly it remains level. Obviously then the impact causes its motion to be retarded relative to *something* to which the motion of the grounded bucket is not retarded, and something capable of causing physical effects, not on the surface only, but throughout the mass of the water, for the splashing is not a mere surface effect. And what can that something be? It must be some third frame, and presumably the same one which produced the physical effects in the rotating bucket. Thus in translatory as in rotary acceleration the water can detect the third frame, even if our eyes cannot, and from its visible behavior we can infer the third frame as well from translatory as from rotary acceleration. And this third frame is the ether. Thus Newton's bucket used in a way varying a little from the way in which Newton used it detects absolute translatory motion as unmistakably as it detects absolute rotary motion. Nor can any physicist who will carefully attend to the evidence deny this. *At any rate, if he does, he must deny absolute rotary motion also, since the argument is the same in both cases.* And this would be proving decidedly too much, for, as we have seen, no physicists, not even the relativists, deny absolute rotary motion. The fact is that the argument from Newton's bucket is not a question of the concavity, or splashing, of accelerated liquids, or of the jerking of accelerated solids *per se*. It is a question of the *asymmetry* of these inertial effects. If both buckets behaved alike in all cases, as they do in the special case where their masses are the same, no third frame of reference could be inferred, no matter how pronounced the concavity or splashing or jerking. It is the *inequality* of the effects, whether translational or rotational, which proves inequality of acceleration and hence absolute motion. The distinction between the kind of motion which can, and that which cannot, be detected by experiments on the earth, has been mistaken by the relativists. The distinction is not that between rotary and translatory motion, as they maintain. It is between accelerated and non-accelerated motion. The arguments from rotary and translatory acceleration stand or fall together. If one is fallacious the other is also.

But again the objection may arise that the earth has something to do with the matter; that it can exert an inertial effect such as that which causes the water in the carried pail to rise and even spill over, as well as a gravitational effect which tends to hold it down. But unless our arguments relative to this objection in the case of the rotating bucket are incorrect, this supposition must be a false one. The earth is no absolute frame of reference. The carried bucket, like the rotating bucket, is the one which we observe moving relative to ourselves while the other bucket is observed not to move. But if we were observers on the carried or the rotating bucket the opposite would be the case, just as on a moving railway train the earth appears moving in the reverse direction, or when we spin rapidly round, the earth appears to spin in the opposite direction. To regard ourselves as the absolute observers in the universe and all others as non-absolute is unreasonable and arbitrary. But the movement of the water *relative to its bucket* is the same for all observers. And so is the non-movement of the water relative to *its* bucket. The carried bucket will be observed to splash and the grounded bucket not to splash irrespective of whether we are observers on the carried or the grounded bucket. There will be no disagreement between observers about these facts. The inertial effects are absolutely unequal. Even if both buckets were a billion miles from the earth this inequality would be maintained, because it does not depend upon the earth but upon the inequality of the colliding masses. The grounded bucket being attached to the heavy door is more difficult to accelerate than the carried bucket whose mass is much less. Accelerate relative to what? Not to the other bucket. The mutual accelerations are bound to be equal. To what then? And to this question there is only one answer—to some third frame, invisible, but everywhere present, even within the mass of dense bodies. This is shown plainly by detaching the grounded bucket from the door, suspending it in the manner of the carried bucket, and repeating the collision experiment already described. This time both buckets splash equally, because now the masses are equal, and hence both may with equal ease be accelerated—relative to the ether. With a little trouble the same thing may be shown for rotating accelera-

tion also. If we place suitable rollers along the edge of the bottom of the bucket on the shelf in the first described experiment and attach it to the shelf only during the twisting of the rope, releasing it when we release the suspended bucket, we shall find that both buckets rotate relative to the earth (and the ether) and both water surfaces become concave, because now the masses upon which the twisting force of the rope is exerted are equal, and hence they both rotate with equal ease relative to the ether, although in opposite directions.

Condensing the argument from Newton's bucket into a single inference, it may be expressed thus: Between two and only two bodies or frames of reference inequality of acceleration is impossible because acceleration is always relative. But the experiments with Newton's bucket reveal inequality of acceleration, both rotary and translatory. Therefore, the experiments with Newton's bucket reveal more than two frames of reference.

It may perhaps be assumed by some that the inertial argument for the existence of the ether here set forth can be met by the relativists. Perhaps it appears to us to be plausible only because their account of the matter is not here and now available to compare with it. In short it may be supposed that the relativists could refute it if given the opportunity. Well, if any relativists can meet the argument Eddington and Einstein ought to be able to, and it so happens that they have both made the attempt. Their manner of meeting the inertial dilemma in fact is down in black and white where all may read and consider it, and I propose to set forth their attempts in their own words in order that you may judge for yourself whether they confute or confirm the argument here presented. It may seem strange that Einstein and Eddington, who insist that the ether exists, should nevertheless deny translatory motion or acceleration relative to it. And yet this is what they do—or rather it is what they do part of the time; for both of them contradict themselves about this without noticing it. However, we need not digress into these contradictions, since in the attempts about to be cited, to disprove absolute acceleration, we shall find contradictions enough. They do not approach the problem by a literal consideration of Newton's bucket to be sure but use a more complex example

which raises exactly the same inertial issue, and I think I can satisfy you that I am not mistaken in so asserting.

Let us begin with Eddington's attempt. Thus in his book, "The Nature of the Physical World," he expresses himself as follows:

> "It will be instructive to consider an objection brought, I think, originally by Lenard. A train is passing through a station at 60 miles an hour. Since velocity is relative, it does not matter whether we say that the train is moving at 60 miles an hour past the station or the station is moving at 60 miles an hour past the train. Now suppose, as sometimes happens in railway accidents, that this motion is brought to a standstill in a few seconds. There has been a change of velocity or acceleration—a term which includes deceleration. If acceleration is relative this may be described indifferently as an acceleration of the train (relative to the station) or an acceleration of the station (relative to the train). Why then does it injure the persons in the train and not those in the station? . . .
>
> "The cause of injury in the railway accident is easily traced. Something hit the train; that is to say, the train was bombarded by a swarm of molecules and the bombardment spread all the way along it. The cause is evident—gross, material, absolute—recognized by everyone, no matter what his frame of reference, as occurring in the train, not the station. Besides injuring the passengers this cause also produces the relative acceleration of the train and station—an effect which might equally well have been produced by molecular bombardment of the station, though in this case it was not." (Pages 130, 131.)

I ask your particular attention to this attempt to meet Lenard's objection. The first thing to note is that Lenard has raised the same inertial issue as that raised by the experiment with Newton's bucket in its translatory form. The moving train corresponds to the carried bucket and the station to the grounded bucket. The injury to the persons in the train is an inertial effect corresponding to the splashing of the water in the carried bucket, and the non-injury to the persons in the station corresponds to the non-splashing in the grounded bucket. Indeed if a bucket of water were placed on the train and another in the station, it would be found that, on the sudden retardation of the train, the first would splash over and the second would not, so that Lenard's example can easily be converted into a Newton's bucket experiment. Now what is the cause of this unsymmetrical reaction? According to the theory advanced in this lecture it is due to the fact that, relative to the ether, the same force accelerates large bodies less than small ones. It is all a question of relative mass.

The station is attached to a large body—the earth—the train is a small body compared to the earth, and the derailing, or whatever caused the accident, led to a collision of the train with the earth. At any rate a mutual reaction of impact or a series of impacts is what caused their mutual retardation, and the force that each exerted on the other was the same, as much in the colliding train and station as in the colliding buckets, since action and reaction are equal. Yet Eddington nowhere refers to the real cause. He nowhere mentions the relative masses of the colliding bodies. He speaks of a swarm of molecules bombarding the train, but no swarm bombarding the station. Where is this swarm and how does it operate? Nobody knows. What he evidently refers to is the fact that when the molecules of the train come in contact with those of the earth in their mutual collision, the latter through their impenetrability exert forces upon the former which cause mutual retardation. But this is no one-sided exertion of force. The molecules of the train exert a like force upon those of the earth. It must be so. Otherwise by pressing our right forefinger against our left forefinger we could cause a pressure to be exerted on the left finger without causing any pressure to be exerted on the right one. But if you try the experiment you will find this is not so. The impact will be felt by both fingers equally. Eddington is really taking the earth as a unique or absolute frame of reference—a thing he has warned everyone not to do. This is why he says the train—which moves relative to the earth—is subject to bombardment, while the earth (station)—which certainly is not moving relative to itself—is not. In short, if his reasoning is correct, the relative masses have nothing to do with the case. It is always the system moving relative to the earth which is subject to bombardment and the retardation caused thereby. The system at rest relative to the earth is not disturbed because not subject to bombardment. There seems nothing else to be made out of his argument. At least I have been unable to find anyone who can make anything else out of it. A consequence of this reasoning applied to the facts of football is instructive. At the opening of the game it is customary for a player to run forward and kick the ball down the field. But according to Eddington this is impossible. The ball is

the body which is at rest relative to the earth. It corresponds to the railway station and hence is not subject to "molecular bombardment." So the player could only stub his toe while the ball would remain immovable. For his foot moves relative to the earth, and thus, being the counterpart of the moving train, is the only one of the colliding systems subject to the molecular bombardment which causes retardation relative to the earth. How well such an explanation agrees with the facts may be left to the judgment of those who have witnessed a football game.

So much for Eddington's attempt at explanation. Now let us examine Einstein's. He, like Eddington, imagines a railway train moving along its track, but instead of a retardation relative to a "station" he imagines one relative to an "embankment" which is obviously an equivalent frame of reference, and, like the station, is at rest relative to the earth. He then directs attention to the fact that a passenger (observer) in the train experiences a jerk (corresponding to the splash in the carried bucket) when the train is retarded relative to the embankment by the sudden application of the brakes, a jerk which he does not experience when the train is moving uniformly. Einstein then proceeds to explain this peculiar experience of the observer in the train—for a corresponding observer on the embankment experiences no jerk, just as the grounded bucket experiences no splash. And how does he explain it? By a molecular bombardment? Not at all. His attempt to avoid the inertial dilemma in which the theory of relativity finds itself is not in agreement with Eddington's. He attempts a different explanation. It may be found in Section 20 of his book on Relativity, and is as follows:

> "It is certainly true that the observer in the railway carriage experiences a jerk forwards as a result of the application of the brake, and that he recognizes in this the non-uniformity of motion (retardation) of the carriage. But he is compelled by nobody to refer this jerk to a 'real' acceleration (retardation) of the carriage. He might also interpret his experience thus: 'My body of reference (the carriage) remains permanently at rest.' With reference to it, however, there exists (during the period of application of the brakes) a gravitational field which is directed forwards and which is variable with respect to time. Under the influence of this field, the embankment together with the earth moves non-uniformly in such a manner that their original velocity in the backwards direction is continuously reduced." (Pages 69, 70.)

This remarkable passage is worth careful examination. It offers the astounding explanation that the application of the brakes does not retard the train—that remains stationary. It retards the "embankment together with the earth," and of course if the embankment is not moving it cannot be retarded. Which constrains us to inquire, Relative to what is the train at rest and the embankment moving—and retarded? Einstein cannot refer to rest or motion of the two relative to *one another*, because rest and motion are relative. Hence if the train is at rest relative to the embankment, the embankment must be at rest relative to the train, and if the embankment is in motion relative to the train, the train must be in motion relative to the embankment. And what is true of motion is true of change of motion, whether retardation or acceleration. They are both relative. To what then are the postulated conditions of rest and motion relative? There is only one answer. It must be to some third frame of reference, since inequality of motion or change of motion between two and only two systems is impossible. Three is the minimum number of frames of reference where inequality of motion, uniform or non-uniform, is involved, and Einstein postulates inequality. Thus he postulates absolute translatory acceleration, which shows we need look no further than Einstein to discover the repudiation of a basic assumption of the theory of relativity.

Unlike Eddington, Einstein nowhere mentions the fact that a man on the embankment is not subject to a jerk. He gives no sign of noticing this significant fact. Hence he does not face the inertial dilemma pointed out by Lenard at all. He assumes that the jerk *per se* is the only indication of absolute translatory acceleration, and hence devotes his attention to that alone. But, as we have already noticed, it is not the jerk *per se*, but the *inequality* of the jerks on the two systems in collision that raises the question of absolute acceleration, and this question he does not consider at all. Hence his substitution of a gravitational field for an inertial one is irrelevant, and throws no light on inequality of acceleration whether translatory or rotary. What does throw light on it is the existence of the ether, an existence which Einstein does not deny, but on the contrary emphatically affirms. The fact

is that if we compare the passage from Einstein just quoted with that quoted on page 424 we encounter something which I am unable to distinguish from a contradiction. In the passage just quoted Einstein endeavors to disprove absolute translatory acceleration, but in the earlier passage he certainly seems to admit it. For he several times mentions acceleration relative to the ether as something which must occur despite Mach's attempt to avoid it. Now rotation is a kind of acceleration, and if this is the only kind he is referring to, then of course there is no contradiction. But in the closing section of the first paragraph he tells us that "Another thing, which is not perceptible, must be looked upon as real, to enable acceleration or rotation to be looked upon as something real," and in this instance it would seem he must be referring to translatory acceleration, since he speaks of acceleration *or* rotation, and he surely would not intend this to mean rotation *or* rotation. It seems fair to infer, therefore, that he is here maintaining the reality of absolute *translatory* acceleration, which is the very thing he seeks to disprove in the passage quoted from his book Relativity.

Now would such able physicists as Eddington and Einstein make these elemental mistakes in physics if they could give a reasonable explanation of the unsymmetrical effects to be noted everywhere around us when bodies of unequal mass collide? No. These mistakes arise from the fact that they are trying to explain what, on the assumptions of relativity, is unexplainable, and their failure, far from confuting the argument from Newton's bucket, only serves to confirm it. For if a reasonable method of meeting these facts, consistent with the assumptions of relativity, could have been found the relativists would have found it.

The proof of the existence of the ether by means of experiments with Newton's bucket is the most unrefutable known to physics. Gravitational, electromagnetic and optical phenomena afford strong evidence of its existence, and these are well known, but inertial phenomena are conclusive. There is an ether and the inequality of acceleration which reveals it makes it one of the easiest things in external nature to detect—not with the physical eye to be sure, but with the subtler eye of inference. Absolute non-uniform motion is to

be observed around us every day and hour of our normal waking existence, and it is only the unconscious assumption that the earth is an absolute or unique frame of reference that conceals the fact from us. Moreover, when we carefully examine the relativist position, we discover, not only that it involves the assumption of an ether, but of translatory non-uniform motion relative thereto. Thus evidence and authority alike unite in declaring the existence of the ether.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

HYDROGEN ISOTOPE OF MASS 2.

For a long time it has been considered that the nuclei of all hydrogen atoms are the simplest and that the nuclei of all other atoms are composed of hydrogen nuclei and electrons. It has now been found by Harold C. Urey and G. M. Murphy of Columbia University in coöperation with F. G. Brickwedde of the Bureau of Standards that all hydrogen nuclei are not alike but that about one in every 4,000 is itself built up of two ordinary hydrogen nuclei, protons, and one electron. It has, therefore, twice the weight of ordinary hydrogen and is called an isotope of hydrogen because it has the same chemical properties. Its occurrence in ordinary hydrogen is so small that it had to be concentrated before its detection and identification could be made certain. Calculations were made of the vapor pressures of the two kinds of hydrogen which showed that it could be concentrated by the fractional distillation of liquid hydrogen at a low pressure only slightly above its freezing point. Samples were prepared in which the concentration was increased to 1 in 500 or 600. The isotope was detected and identified by means of its spectrum produced by passing an electrical discharge through the gas. The spectrum was analyzed by means of a diffraction grating with a focal length of 21 feet.

HEAT OF VAPORIZATION OF WATER.

A knowledge of the quantity of heat required to convert water into steam under saturation conditions is essential in the design of steam power plants. The bureau, in coöperation with the American Society of Mechanical Engineers, has been making a long series of measurements in the range from 50° to 270° C. Recent determinations at 50°, 70°, and 90° C. give values of 2,381.6, 2,333.6, and 2,283.4 International joules per gram, respectively.

* Communicated by the Director.

The official report on this work will be published in the March number of the *Bureau of Standards Journal of Research.*

INFRA RED ARC SPECTRUM OF PHOSPHORUS.

The spectrum of an element is that one of its characteristics by which its identity is definitely and absolutely established. Very little is known about the arc spectrum of phosphorus, although this element plays such a prominent rôle in the chemistry of biological and industrial processes. The reason for this is that the prominent features of the spectrum lie either in the extreme ultra violet or in the infra red beyond the reach of ordinary spectrographic methods. Recently, at the bureau, that portion of the phosphorus arc spectrum, which lies in the infra red, was photographed for the first time by means of specially sensitized plates prepared by the Eastman Kodak Company. About 40 new wavelengths have been measured and these have been brought into relationship with the ultra violet lines already known, as the result of the discovery of some additional ultra violet lines. The analysis of the wave length data shows that the spectrum agrees in all respects with that required theoretically for the phosphorus atom, with 15 electrons outside the nucleus, five of which are responsible for the observed spectrum. The ionization potential has been found to be 11.11 volts.

Those interested will find a complete report of this work in the March number of the *Bureau of Standards Journal of Research.*

OXIDATION OF ALDOSE SUGARS BY BROMINE WATER.

The oxidation of the aldose sugars to monobasic acids by bromine water is one of the classical reactions which has been considered as evidence for the aldehydic structure for glucose and related sugars. In a recent investigation at the bureau, bromine oxidations of various sugars were followed by the optical rotations of the solutions. A series of remarkable changes was found from which it was concluded that the sugars are not oxidized to the sugar acids as previously believed. The delta lactones are the first products which can be detected by means of the optical rotations. The acids which

appear subsequently are secondary products resulting from the hydrolysis of these lactones. If the fact that the lactone formation precedes the formation of gluconic acid is interpreted to indicate that one ring form of the sugar is oxidized directly to the lactone, it cannot be said whether or not the particular form of the sugar which is oxidized is the predominating form in solution. Nevertheless it is of interest that the delta or 1, 5 lactone is found in solution after the oxidation of a solution containing normal glucose which supposedly contains a 1, 5 ring structure. A complete report of this study will appear in the March number of the *Bureau of Standards Journal of Research.*

DESIGN OF DOMESTIC GAS BURNERS.

Investigations covering 16 years at the Bureau of Standards have shown that there are four important conditions which should be fulfilled by a domestic gas burner: It should not go out, it should not flash back, it should be an efficient heat producer, and it should not produce carbon monoxide. On first thought it may appear a simple matter to design a burner which will fulfill these conditions, but since they are all so inter-related and in some ways contradictory, and, moreover, are so influenced by other conditions of use, the matter of a satisfactory design is quite complicated and difficult.

The subject has only received attention during comparatively recent years. The first gas company in the United States was organized in Baltimore in 1816, but for at least 80 years gas was used almost entirely for lighting. Not until 1900 was gas employed to any extent for cooking, and it was not until 1916, one hundred years after the introduction of gas into the United States, that the bureau was first called upon to study the design of atmospheric gas burners. During the War when coal was difficult to obtain the use of gas for heating purposes became much more common than before, and owing to the use of poorly designed appliances a considerable number of accidents occurred. Since 1916 the bureau's work, has, therefore, included a study of the efficiency and safety not only of the gas burner but of the applicance. The various factors which limit the design of gas burners, flashing back,

lifting of the flame from the burner, and incomplete combustion which results in the liberation of either carbon monoxide or soot and yellow flame, may be plotted as curves, thus showing graphically the limits within which a successful burner must operate.

The apparatus used at the bureau in studying burners is designed to facilitate the determination of the proportions of a well designed burner. The size of the ports is determined by the probable rate of gas consumption and the heat content of the gas as well as by the time allowable for a given heating operation. Having determined the size of ports, the throat area of the burner should be 40 per cent. of the total port area and the length of the injection tube six times the throat diameter, the walls expanding with a two degree slope from the smallest diameter which occurs near the tip of the orifice through which the gas is injected into the tube. The air which is mixed with the gas in this tube is known as the primary air but this air is never sufficient in amount to burn the gas completely. Secondary air must, therefore, have free access of the flame to complete the combustion. The shape of the burner, distance between the ports, and the distance from the burner to the utensil are, therefore, important considerations.

As the result of this work it is possible to design an efficient and safe burner which will operate within any reasonable limits of gas consumption and composition. It is of interest to note that to meet widely different conditions, such as exist in communities served with natural and artificial gas, manufacturers are supplying burners of slightly different proportions, each best adapted to the gas available where they will be used. Atmospheric pressure, which varies with altitude, also has a slight effect, an appliance which would be perfectly satisfactory at Washington being not so well adapted to service in Denver, for instance. Atmospheric humidity has so slight an effect that it may be disregarded. This subject of gas burner design has been in part discussed in Circular No. 394 which may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 10 cents per copy; another paper in preparation will cover the remainder of the subject.

WEATHERING OF SOLDERED AND TINNED SHEET COPPER.

Accelerated weathering tests of tin- and solder-covered copper may be made in humid atmospheres containing 1 per cent. SO_2, 5 per cent. CO_2, and 94 per cent. air by volume, if maintained around 50° C. or over. In the March number of the *Bureau of Standards Journal of Research* results are given in tabular form showing that tin and electrotinned copper are but slightly attacked by the above atmosphere. On the other hand, heat-treated electrotinned copper and hand-tinned copper are badly corroded and very badly pitted, while soldered copper, if heated to high temperatures previous to weathering, is markedly furrowed, resulting in a decrease not only of the strength of the sheet at the joint but also of the number of bends required to produce failure. The pitting is due to the formation of a brittle copper-tin layer which, upon cracking, exposes copper and forms the cathode of a galvanic cell with it. The furrowing of copper at the solder-copper junction is also due to similar galvanic action.

Microscopic study revealed that the copper alloyed with the molten tin of the tin coating or of the solder to form definite layers. The layers of tin-copper alloys adjacent to the sheet became richer in copper the higher the temperature used during tinning or soldering. The pitting of copper caused by galvanic action set up between these copper-rich alloys was considerable. At lower temperatures, less alloying occurred, with the result that the tin coat contained very little copper and the pitting and furrowing were markedly diminished.

Poor technique in the use of flux is not the cause of seam corrosion, but can cause pitting of copper. The prevention of seam corrosion and pitting of copper coated with tin-bearing materials lies in the prevention of the formation of copper-tin alloys. The corrosion can be reduced to a minimum by using low temperatures during tinning and soldering.

PAPER FROM RAW COTTON.

The prevailing low price of raw staple cotton is directing attention to the possibility of using it for making paper. Cotton producers are interested in finding new or enlarged

outlets for this material because the increasing use of synthetic fibers for textiles, and other adverse economic developments are leading to the accumulation of an increasing surplus of this important agricultural crop.

Next to the textile industry, the paper industry is the largest consumer of cellulose. In view of the many inquiries received by the bureau concerning the paper industry as a potential user of raw staple cotton, the question was discussed with various users of cotton fiber for paper-making. The consensus of their opinions is as follows.

Raw staple cotton as produced at the present time cannot compete with the highest grade of textile cotton wastes used for paper-making as the price differential still favors the latter considerably, and any lowering of the price of staple cotton is reflected in the price of the textile wastes. There is considered to be no great difference in the way the two different classes of materials react in the paper-making processes or in the quality of paper prepared from them. Cotton linters, the shorter cotton strands left after removal of the staple cotton, and which is lower in price, is used to some extent in the paper industry but it appears to lack, for most purposes, some of the desirable paper-making properties possessed by the textile wastes.

From the above opinions, it appears that the use of raw staple cotton for paper making hinges largely on the economic factors, and probably the only way the present unfavorable cost ratio could be overcome would be by the production of the staple cotton on a generally mechanized basis. According to a recent news item, study in this direction is being made at the University of North Carolina. It is of interest that, according to historical records, raw cotton was the first source of cotton fibers for paper making, being largely used, apparently, from the 7th century until the 11th century when it began to be displaced by waste textile materials.

MASONRY CEMENTS.

The tests of the masonry cements outlined in Technical News Bulletin No. 174 (October, 1931) have brought out the great variation in their properties. Measurements were made

of the spread upon a plate of the neat pastes dropped from an apparatus similar in principle to the Saybolt viscosimeter. The ratio of the weight of cement to water to produce pastes having the same spread varies from 1 : 1 to 2.8 : 1. The apparent specific gravity of the pastes varied from 0.83 to 1.93. The apparent specific gravities of the mortars made from the cements have been found to range from 1.59 to 2.24. The variations in these specific gravities appear to be some function of the amount of waterproofing material contained in the cement and of the weight of the cement per unit volume.

When equal amounts of sand are added to equal amounts of pastes having the same neat spread the resulting mortar does not have equivalent flows on the flow table, these flows varying from 56 to 160. The range in seven day compressive strength of a 1 : 3 by volume mix, using a mixture of standard and pit run Ottawa sand as aggregate varies from 15 to 4,085 lbs./in.^{2} The yields of the mortars vary considerably. The water requirement to produce a mortar flow of from 100 to 115 on the standard ten inch flow table varied from .73 to 1.35 by volume. The cements requiring the greatest amount of water would not, as might be expected, give the greatest yield.

The plastic measurements on the modified McMichael viscosimeter varied from 510 to 2,360 for mortar mixes that all had a flow table measurement of 100. Certain cement mortars show a decrease, some an increase, in flow table measurement due to the mixing given in the plasticimeter, all mortars being given the same amount of agitation. Within the plastic limit the cements have a range of from 200 to 1,200 grams shear resistance. The amount of water that could be added to a cement and have the mortar remain within the plastic range varied from 5 to 6 per cent., with but few exceptions. This is true for cements requiring small amounts as well as large amounts of water. Thus at one extreme a cement was plastic with from 11 to 17 per cent. water and at the other extreme a cement was plastic with from 24 to 29 per cent. of water.

RELATION BETWEEN DENSITY AND REFRACTIVITY OF SOME GLASSES.

The work on the relations between density and index of refraction of soda-silica glasses containing from about 50 to 80 per cent. soda, has led to the conclusion that the changes in density and index of refraction with composition can be represented more accurately by straight lines than by a single continuous curve. When the density or index of refraction of the soda-silica glasses is plotted against the silica or soda content of the glasses, there is a definite change in the slope of the line at points whose composition would correspond to soda-silica ratios 4 : 6, 3 : 6 and 2 : 6.

The relation between index of refraction and density is strictly linear and can be expressed by $N = 1.8668 - 0.899\ V$, in which N is the index of refraction for yellow light and V is the reciprocal of density or specific volume. For glasses containing lime and magnesia the above equation holds if one adds to it 0.00114 times the percentage of lime and 0.00055 times the percentage of magnesia in the glass.

THE FRANKLIN INSTITUTE.

STATED MONTHLY MEETING, MARCH 16, 1932.

The regular monthly meeting of The Franklin Institute was called to order at eight-fifteen p.m. by Mr. Nathan Hayward, the President, who presided.

The Chairman called for the minutes of the last meeting. Mr. Rigling, Assistant Secretary (the Secretary being absent because of illness) reported that the minutes of the last meeting had been printed in full in the March number of the JOURNAL. He stated that, if there were no objection, he moved that the minutes be approved as printed. No objection was uttered and the minutes were declared approved.

The Chairman then called for new business. The Assistant Secretary reported that, since the last monthly meeting six resident members and one non-resident member had been elected. He also announced with regret the death of three members of the Institute.

There being no further business, Mr. Hayward introduced the speaker of the evening, Mr. R. D. Parker, of the American Telephone and Telegraph Company in New York City. Mr. Parker delivered a very interesting talk on "Teletypewriters and Teletypewriter Service." His paper was accompanied by several demonstrations upon machines which had been set up. The subject was one of wide appeal and attracted a large audience.

The meeting adjourned at nine-fifty p.m. with a rising vote of thanks to the lecturer for his exceedingly interesting demonstration and delivery.

ALFRED RIGLING,
Assistant Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of Stated Meeting held Wednesday, March 9, 1932.*)

HALL OF THE COMMITTEE,
PHILADELPHIA, MARCH 9, 1932.

MR. EDWARD L. CLARK *in the Chair.*

The following reports were presented for final action:

No. 2946: Diffraction of Electrons by Thin Films.

This report recommended the award of the Howard N. Potts Medal to Professor George Paget Thomson, of the Imperial College of Science, London, England, "In consideration of his brilliant experimental demonstration of the wave properties possessed by high speed electrons."

No. 2952: Clark Medal.

This report recommended the award of the Walton Clark Medal to Mr. Philip T. Dashiell, of Philadelphia, Pennsylvania, "In recognition of his outstanding contributions to the carburetted water gas industry as embodied in his fuel oil carburetion process."

No. 2953: Literature.

This report recommended the award of the Louis Edward Levy Medal to Doctor Wayne B. Nottingham, Assistant Professor of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts, for his paper on "Characteristics of Small Grid-Controlled Hot-Cathode Mercury Arcs or Thyratrons," which appeared in the March, 1931 issue of the Institute's JOURNAL.

The following report was presented for first reading:

No. 2940: Development of Method of Symmetrical Coördinates.

GEO. A. HOADLEY,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, March 16, 1932.*)

RESIDENT MEMBERSHIP.

MR. M. L. BLUMENTHAL, Illustrator and Writer, 349 East Church Road, Elkins Park, Pa.

PROF. F. O. DUFOUR, Consulting Engineer, United Engineers and Constructors, Inc., 112 North Broad Street, Philadelphia, Pa.

MISS EDITH M. HOARE, Librarian, R C A Victor Company, Camden, New Jersey.

MR. ROLAND W. JOHNSON, Sales-Engineer, A B See Elevator Company, Inc., Philadelphia, Pa. For mailing: 2499 North Fiftieth Street, Philadelphia, Pa.

MR. ABBOTT FULLER RIEHLE, President, Riehle Bros. Testing Machinery Company, 1424 North Ninth Street, Philadelphia, Pa. For mailing: 3433 Midvale Avenue, Philadelphia, Pa.

MR. CLINTON Y. WILGUS, Chemical Engineering, Electric Storage Battery Company, Philadelphia, Pa. For mailing: 200 Wellington Road, Jenkintown, Pa.

NON-RESIDENT MEMBERSHIP.

MR. A. GRISWOLD HERRESHOFF, Mechanical Engineer, Vice-President Fargo Motor Corporation, Detroit, Michigan. For mailing: 111 Highland Avenue, Highland Park, Michigan.

CHANGES OF ADDRESS.

MR. JOHN H. GILLIES, 211 Drexel Court Apartments, Drexel Hill, Pa.

DR. JOHN H. PERRY, The Grasselli Research Laboratory, Grasselli Chemical Company, Cleveland, Ohio.

MR. JOHN STONE STONE, 3100 Brant Street, San Diego, California.

MR. S. N. VAN TRUMP, Silverside Road, Edge Moor, Delaware.

NECROLOGY.

Mr. W. L. Austin, Philadelphia, Pa.
Mr. J. J. Kennedy, Brooklyn, New York.
Dr. S. A. Williams, Bel Air, Maryland.

LIBRARY NOTES.

RECENT ADDITIONS.

American Society for Testing Materials and American Foundrymen's Association. Symposium on Malleable Iron Castings. 1931.

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OSTRANDER, TOBIAS. The Planetarium, and Astronomical Calculator. 1832.

PAGÉ, VICTOR W. The Chevrolet Six, Car and Truck. 1932.

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PRENTIS, EDMUND ASTLEY, AND LAZARUS WHITE. Underpinning: Its Practice and Applications. 1931.

PRIESTLY, JOSEPH. Discourses on Various Subjects, Intended to Have Been Delivered in Philadelphia. To which Are Added Some Others, Selected from the Same Author. 1805.

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SHEWART, W. A. Economic Control of Quality of Manufactured Product. 1931.

SMEE, ALFRED. The Potato Plant, Its Uses and Properties: Together with the Cause of the Present Malady. 1847.

STINE, WILBUR M. Contributions to the Discovery and Physics of the X-Ray. 1892–1897. Two volumes.

STOLLER, H. M., F. E. AUSTIN, AND E. W. SEEGER. Small Motors, Transformers, Electromagnets. 1931.

STUKER, P. Stern-Atlas für Freunde der Astronomie. Teil 1–3. No date.

THOMAS, JOHN J. Farm Implements and Farm Machinery, and the Principles of Their Construction and Use. New edition. 1883.

UNDERWOOD, G. Standard Construction Methods. Second edition. 1931.

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WARNER, EDWARD P., AND S. PAUL JOHNSTON. Aviation Handbook. First edition. 1931.

WEBB, WALTER LORING, AND W. HERBERT GIBSON. Concrete Design and Construction. 1931.

Wien-Harms Handbuch der Experimentalphysik, Band 4, Hydro- und Aerodynamik; 2 Teil, Widerstand und Auftrieb. 1932.

WILSON, JOSEPH M. History, Mechanics and Science. No date.

BOOK REVIEWS.

PHYSIKALISCHES HANDWORTERBUCH, by Arnold Berliner, Dr.-Ing. e.h., Dr. phil. and Karl Scheel, Geh. Reg.-Rat, Prof. Dr. phil., second edition, vi–1428 pages, figures, quarto., Berlin, Julius Springer, 1932. Price, in paper, 96 R.M.

This abridged dictionary of physical terms is now enjoying the distinction of a second edition. The justification for this revised and enlarged issue, published seven years after the first, may be found in the fact that our knowledge of things physical has so increased in this period that this edition is now 525 pages larger than its predecessor.

In order to preserve the unity of a single volume, the numerous articles must of necessity be abridged. However, these limitations have not applied to the choice of terms comprising this dictionary. The authors have embraced a very wide field and covered all subjects related to classical and modern physics. This includes such fields as astronomy, astrophysics, meteorology, navigation, geophysics, geodesy, geology, mathematical and philosophical concepts as they apply to the neo-physics, and such chemical and physiological terms as may directly relate to physical investigations in these fields.

This dictionary should prove a great convenience to the physicist particularly in the fields complimentary to those in which he specializes. In a similar way the non-physicist will find this compendium a valuable and convenient reference work.

T. K. CLEVELAND.

COURS D'ÉLECTRICITÉ THÉORIQUE PROFESSÉ À L'ÉCOLE PROFESSIONNELLE SUPERIÈURE DES POSTES ET TÉLÉGRAPHES. Par J. B. Pomey, Ingenièure en Chef des Postes et Télégraphes. Tome III—T. S. F. et Cable Téléphonique —Théorie Mathematique, 318 pages, 8vo, paper. Paris, Gauthier-Villars et Cie., 1931. Price 90 francs.

The third volume of this highly analytical work which now appears, the second of which was noticed in these pages, like those that precede, very freely employs those modern methods of analysis which, once only currently used by

the *élite* among mathematical physicists, are coming more and more within the reach of advanced readers of mathematical physics. That the reader may be spared a possibly irksome search in mathematical literature for data on the development of these processes, the author has thoughtfully introduced chapters on the principles of tensorial calculus, relativity, theorem of invariance of the equations of the magnetic field, and an introduction to the study of the Rieman-Christoffel tensor. The particular topics treated are: the propagation of hertzian waves, dielectrics, long-distance cable telephony, artificial alternating-current lines, generation and distribution of the current, and electric circuits. In the last-named, the Heaviside method, as interpreted in the recent work of Carson, is freely drawn upon. Many bibliographical references are recorded in the text. The processes employed harmonize with the methods of modern physical research.

L. E. P.

THE MARION EXPEDITION TO DAVIS STRAIT AND BAFFIN BAY UNDER THE DIRECTION OF THE UNITED STATES COAST GUARD, 1928. Scientific Results, Part 3, Arctic Ice, with Especial Reference to its Distribution to the North Atlantic Ocean, by Edward H. Smith. 221 pages, illustrations, maps, 14.5 x 23 cms. Washington, Government Printing Office, 1931.

The International Ice Patrol, established in 1913 as a result of the Titanic catastrophe, has been going about its duties so quietly that its very existence is a surprise to many people. Beside the practical work of patroling ship lanes and sending out warnings of the position and drift of icebergs, the Ice Patrol has carried out a scientific program of collecting and correlating data and has thus accumulated a vast store of knowledge regarding Arctic ice at its southern-melting end. To complete the picture there was need for a similar study of the ice from its northern sources to Newfoundland, and to this duty the Coast Guard Cutter *Marion* was assigned in the summer of 1928.

The principal task of the expedition was the measurement and recording of temperature and salinity from selected points of observation and depth. Over two thousand such observations were made. By correlation with the various earlier data it is now possible to present a connected picture of Arctic ice and of its southward drift. The present volume covers this phase of the report. (For those interested, Parts I and II, published separately, cover respectively the bathymetry of Davis Strait and the physical oceanography of the Strait with especial reference to the circulation of those waters.)

Of interest to the lay reader is the conclusion that "the major controls of thermal equilibrium of the North Atlantic are the ocean currents, while the direct action of vernal warming in the ice areas themselves . . . is secondary. . . . The chilling as a result of melting ice amounts to approximately one-half the solar heating which this same region receives during the summer," and it is "only 10 per cent of the total cooling that the Atlantic receives from the cold water masses of the Labrador current. . . . Obviously the low temperature character of the Labrador and east Greenland currents is not due to the melting ice with which these streams are charged in spring and summer. These ocean currents are cold because of the small amount of solar radiation of the earth's surface in the polar regions."

The report also points out that "the energizing forces resulting from melting ice are not adequate to produce the circulatory mechanism of the world's oceans. . . . Ice melting over the North American and east Greenland shores helps to accentuate the contrast between coastal and oceanic waters, thereby intensifying the currents, but emphatically it is not the main cause of propulsion nor is it even a necessary attribute thereof."

An obvious error appears on page 111. In the report of specific gravity determinations of a piece of berg-ice the lowest density is given as 0.8977, the highest as 0.9045, and the mean as 0.8977.

Although essentially a technical report, this is a decidedly readable document. It contains many very fine photographs, numerous maps, and an excellent bibliography. The maps would have been more helpful to the casual reader if some distinguishing and well-known landmarks had been shown.

C. H. JEGLUM.

THE UNIVERSE UNFOLDING. By Robert H. Baker, Ph.D., Professor of Astronomy University of Illinois. 140 pages, ill., 12.5 x 19 cms. Baltimore, The Williams and Wilkins Company, 1931. Price $1.00.

This little volume is the second in the "Century of Progress Series," which is published in collaboration with the Advisory Committee on Scientific Publications of the Century of Progress International Exposition, to be held in Chicago next year. The Advisory Committee is headed by Dr. Henry Crew, former Professor of Physics at Northwestern University. As is well known, the Century of Progress Exposition is intended "to depict graphically and systematically the last hundred years of intellectual endeavor," to quote from a statement on the jacket of this book. The "Century of Progress Series" is a part of this programme and the list of titles, most of which are now in preparation, includes all branches of science. The first one published was "The Queen of the Sciences," by E. T. Bell, the "story of mathematical progress." It is appropriate that the series should be started with mathematics and that astronomy should follow immediately afterwards, for mathematics is at the basis of all science and astronomy is the oldest of the sciences.

Professor Baker has produced a very interesting book in which he shows how the universe of the ancients, with the stars on a solid sphere only a short distance beyond the planets, has expanded to one in which distances of millions of light years are common yet the end, if any, is far more distant. In tracing this development an account is given of such interesting subjects as the methods of determining stellar distances, the dark nebulae, or clouds "of cosmic dust," the nature of the Milky Way system, and the apparent high speed of recession of the distant galaxies. Eight half-tone plates, from excellent astronomical photographs, and seven text figures, add to the book's interest. It is a pity, however, that the publishers have not seen fit to include an index and it is to be hoped that this defect will be remedied in future printings and in other books to appear in the series.

JAMES STOKLEY.

ASTRONOMY MADE EASY. By William E. Johnson, Chief, Department of Cartography, Rand McNally and Co. 119 pages, ill., 12.5 x 19 cms. Chicago, Ill. Rand McNally and Co., 1931. Accompanied by 8 inch celestial globe. Price $12.00 to $30.00, depending on mounting of globe.

A century ago the celestial globe was an inseparable companion of the terrestial one, but, along with the decreased general knowledge of the heavens in our modern civilization, the celestial sphere is a curiosity to many people. With the increased interest in astronomy that is bound to come as more planetaria are established there should be a greater desire to know the constellations. Because of the unavoidable distortions in representing a sphere on a plane surface, a celestial globe remains the best simple means for studying the constellations.

The Rand McNally and Company deserve the cordial thanks of astronomers in general for this effort to repopularize the celestial globe. Attractively mounted, the new globe shows the brighter naked eye stars in yellow against a dark blue background. The constellation figures, their names, and the names of the brightest stars are indicated in a lighter blue. A novelty has been introduced by indicating on the meridian ring the polar distance, instead of the declination. Thus, the globe may be set for any place by setting the polar distance, equal to the latitude, at the Northern horizon. The setting of the globe to any hour has also been simplified by the use of a disc indicating the time of day or night attached to the meridian ring at the North Pole. Concentric with this, on the globe itself, is a circle of dates of the year. Therefore, to rectify the globe for any time or place it is only necessary to set the meridian ring to the latitude and to turn the globe so that the hour is opposite the date. As a further convenience, there is given on the horizon ring a table of latitudes of places throughout the world.

The globe is furnished in four models, all but the cheapest with the full mounted ball and horizon ring. The book by Mr. Johnson accompanying the globe gives not only full directions for its use, but also includes a very complete summary of astronomical knowledge. This has been carefully prepared and seems quite accurate, except that the distance of Polaris is given as 47 light years instead of 272, which is the figure derived from the latest parallax measurements.

JAMES STOKLEY.

GRUNDBEGRIFFE DER CHEMIE (FUNDAMENTAL CONCEPTS OF CHEMISTRY). By Dr. E. Rabinowitsch, Göttingen. 151 pages, 2 figures, 10.5 x 16 cms. Walter de Gruyter & Co., Berlin and Leipzig, 1930. Price, RM 1.80.

This handy pocket-sized volume is the 804th member of the Göschen series. As the title implies, the author intends this work to serve as a starting point for those desiring a broad and comprehensive perspective of the science of chemistry. The book may be compared to the so-called vanishing point of an enormous picture, at which point the field is so narrowed and condensed only the more outstanding generalities remain. Not only the student but the practical chemist will find many helpful facts and hints in this text. Workers in closely related sciences should secure considerable benefit from this concise compendium of chemical concepts. Those who had their chemistry many years ago will be pleased to find that increasing knowledge has established appropriate position for what then seemed to be a mass of anomalous facts.

The volume consists of two parts. The first deals with the elements and chemical compounds. As such it discusses the various states of matter and its structure. The second portion deals with chemical reactions paying particular attention to their free energies, heats, rates and equilibriums.

T. K. CLEVELAND.

PUBLICATIONS RECEIVED.

Allen's Commercial Organic Analysis, a treatise on the properties, modes of analysis, and proximate analytical examination of the various organic chemicals and products employed in the arts, manufactures, medicine, etc. Vol. IX. The Proteins of Plants, the Proteins of Milk, Milk, Milk Products, Meat and Meat Products. Editor, C. Ainsworth Mitchell. Fifth edition, revised and partly rewritten. 617 pages, tables, 8vo. Philadelphia, P. Blakiston's Son & Co. Price $7.50.

An Introduction to the Mathematics of Map Projections, by R. K. Melluish, 144 pages, illustrations, 8vo. Cambridge, The University Press, New York, The Macmillan Company, 1931. Price $3.00.

Wasserkraft Jahrbuch, 1930–1931, 370 pages, illustrations, 8vo. Munich, G. Hirth, 1931.

The Universe Unfolding, by Robert H. Baker, A Century of Progress Series, 140 pages, plates, tables, 12mo. Baltimore, The Williams & Wilkins Co., 1932. Price $1.00.

National Research Council, Bulletin No. 86, Bibliography of Bibliographies on Chemistry and Chemical Technology, Second Supplement, 1929–31, compiled by Clarence J. West and D. D. Berolzheimer, 150 pages, 8vo. Washington, National Academy of Sciences, 1932. Price $1.50.

Licht Gestaltet Physik, Erkenntniskritische Untersuchung der physikalischen Gestaltung, grundsatzliche Sicherung der Lorentz-Transformation und Aufhebung der speziellen Relativitatstheorie, von Otto Brühlmann, 47 pages, illustrations, 8vo. Wien, Wilhelm Braumüller, 1932. Price 7.80 marks.

Abridgment of a Paper read by Mr. Alfred J. Buechi, Winterthur, Switzerland, on the "Merits of Turbo-Charging of Diesel Engines," at a meeting on the 29th May, 1931, and 10th June, 1931, of the Kikai Gakkai and Zosen Kyokai, Tokyo and Osaka, 29 pages, illustrations, quarto.

Bell Telephone Laboratories, Monographs: No. B-619, The Time Factor in Telephone Transmission, by O. B. Blackwell, 18 pages, illustrations, 8vo. No. B-636, A New High Vacuum System, by J. A. Becker and E. J. Jaycox, 12 pages, diagrams, 8vo. B-637, Some Contemporary Advances in Physics—XXIII, Cosmic Rays, by Karl K. Darrow, 37 pages, illustrations, 8vo. B-638, The Operation of Vacuum Tubes as Class B and Class C Amplifiers, by C. E. Fay, 25 pages, illustrations, 8vo. B-639, The Cathode Ray Oscillograph, by J. B. Johnson, 27 pages, illustrations, 8vo. B-640, Constant Frequency Oscillators, by F. B. Llewellyn, 34 pages, illustrations, 8vo. B-641, Some Physical Properties of Wiping Solders, by D. A. McLean, R. L. Peek, Jr., and E. E. Schumacher, 25 pages, illustrations, tables, 8vo. B-642, Regeneration Theory, by H. Nyquist, 22 pages, illustrations, 8vo. B-643, Forecasting Population for Engineering Purposes, by

James N. Holsen, 17 pages, 8vo. B-644, Rapid Record Oscillograph in Sound Picture Studies, by A. M. Curtis, T. E. Shea, and C. H. Rumpel, 15 pages, illustrations, 8vo. B-645, Tape-Armored Telephone Toll Cable, by C. W. Nystrom, 14 pages, illustrations, 8vo. New York, 1932.

National Advisory Committee for Aeronautics, Technical Notes No. 408, Preliminary Tests on the Vaporization of Fuel Sprays, by A. M. Rothrock, Langley Memorial Aeronautical Laboratory, 4 pages, illustrations, quarto, Washington, Committee, 1932. No. 409, Effect of Aging on Taut Rubber Diaphragms, by D. H. Strother and H. B. Henrickson, Bureau of Standards, 7 pages, tables, illustrations, quarto. Washington, Committee, 1932.

CURRENT TOPICS.

New Source of Sugar Supply. It has been discovered by recent experiments that the Jerusalem artichoke is a source of a sweeter sugar than is yielded by either sugar beet or cane. It is considered likely that farmers in Ireland will take up the growing of these artichokes after further experiments have been carried out, as they will grow in almost any soil, while the leaves make good feed for horses. (A. E. B., *Scientific American*, March 1932.)

R.

Do We Eat Too Much?—The U. S. Department of Agriculture Clip Sheet No. 711 quotes DR. O. E. BAKER, economist of the department, as saying that it takes more than two acres of crops to produce food for an American, but it takes only one acre for a German, one-half an acre for a Chinese and only one-fourth an acre to feed a Japanese. Dr. Baker points out that these differences in the acreage of crops needed to feed one person are due principally to differences in diet. However, twice as much land is necessary to produce food for a Chinese as for a Japanese because crop yields are much higher in Japan.

T. K. C.

Statistics Electrical.—A report issued by the Geological Survey, U. S. Department of the Interior, states that the production of electricity by public-utility power plants in 1931 showed a decrease of 4 per cent. from the output of 1930. Nevertheless, the amount consumed came to no less than 91,679,232,000 kilowatt-hours, 33.3 per cent. of this quantity was produced by water power. It also is interesting to find that within the last 12 years the increase in water power has not kept pace with that of fuel. In 1919, 37.5 of the total electricity consumed owed its origin to the so-called "white coal."

More interesting still is the fact that the consumption of coal and coal equivalent of oil and gas was 3.2 pounds per kilo-watt hour in 1919 and only 1.55 pounds in 1931. This conservation of fuel effected by the operators of public-utility plants in the past 12 years amounts to 325,000,000 tons of coal or its equivalent and represents a saving of over a billion dollars. The use of coal and oil for fuel in steam power plants in 1931 as compared with 1930 showed a decrease of 10 and 13 per cent. respectively. The use of natural gas increased 15 per cent.

T. K. C.

Training in Radio Communication.—Recognizing the need for a course of instruction intermediate between that for a skilled craftsman and the trained profession engineer, the Extension Division of the University of Wisconsin located at Milwaukee is offering such a course, the purpose of which is to fit students for advanced places in radio activities. The course is very intensive, requiring the entire time of a student for two semesters. Taken by correspondence, the required time may be somewhat longer. Satisfactory completion of the course qualifies the student for the government examination for a Second Class Commercial Operator's License.

T. K. C.

Injurious Reducing Drugs.—(Office of Information, U. S. Department of Agriculture.) According to Dr. F. J. Cullen, chief of the Federal Food and Drug Administration's drug control unit, the majority of so-called "fat reducers" offered for sale contain either thyroid extract or laxative drugs. Thyroid extract is a dangerous drug. It may cause a loss of weight in individuals who are suffering from a certain disease affecting the thyroid gland and should always be administered under the care and direction of a physician.

Many products containing laxatives also may contain a poisonous drug, polk root (commonly known as "Poke Weed"). These preparations will cause a loss of weight in some people, due to their cathartic effects and the irritation set up in the stomach and intestines. After using a short time, their discontinuance is usually followed by an increase in appetite and weight.

T. K. C.

Age-Hardening.—In the annual lecture of the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers, DR. PAUL D. MERICA of the International Nickel Company, Inc., stated that many metals and alloys hitherto mechanically inferior to steel may now be brought up to the standard of steel, as far as mechanical properties are concerned, through the development within the past decade of a process known as age-hardening. All the common metals may now be alloyed in such a manner as to render them susceptible to age-hardening. Copper may be hardened to about 400 Brinell, a value comparable with that of spring steel. Copper-nickel alloys may be heat-treated to exhibit tensile strengths in the neighborhood of 175,000 pounds per square inch, also comparable with the strength of heat-treated steel.

Explaining the process of age-hardening, Dr. Merica said: After certain heat treatments, these age-hardening alloys harden as they

grow older. Some will age-harden at room temperatures others must be held at higher temperatures. A single day is often adequate to bring about these desired changes in mechanical properties, although slight changes may continue to occur for a month. This so-called age-hardening consists in the formation throughout the metal or alloy of large quantities of extremely fine, sub-microscopic particles of the hardening constituent. These particles are less than 1/100,000 of an inch in diameter and are formed from the constituents of the alloy itself. The condition of the hardened alloy is very similar to that found in the alloy, "babbitt." That is, large numbers of very hard particles are embedded in a matrix of softer material.

T. K. C.

The Philadelphia Industrial Area.—The Department of Commerce Bureau of the Census released this past month its report of the 1929 Biennial Census of Manufactures for 1929. The "industrial area" of Philadelphia, as defined by the Bureau of Census, includes five counties in the State of Pennsylvania and three in the State of New Jersey. Within this area there were 7,184 manufacturing establishments in 1929 with products valued at $2,981,045,661. During the year these establishments employed 376,009 wage earners the total payrolls amounting to $510,540,601. One-third this amount also was paid to one-sixth as many salaried officers and employees.

The ten industries leading in value of products produced are given in order starting with the highest. They are: petroleum refining, knit goods, electrical machinery, apparatus and supplies, printing and publishing of newspapers and periodicals, foundry and machine-shop products, steel works and rolling mills, clothing (except work clothing) worsted goods, sugar refining, bread and other bakery products.

T. K. C.

Running a Ford on Low Temperature Coke.—In the January 22, 1932, issue of *Chemistry and Industry*, ALEC WEBSTER describes cases where a motor truck and tractor were successfully operated on producer gas from low temperature coke. The only alterations necessary were the installation of a small portable gas producer and scrubber on the chassis and the installation of a different cylinder head permitting the engine to operate more efficiently.

The producer consists essentially of a fuel hopper superimposed on a small combustion chamber. A special type of grate avoids clinkering troubles. The producer is so arranged it can be worked

on an up-draft; down-draft or both combined. The water supply is regulated by a needle valve and is allowed to flow either into a vaporizer above the refractory or into the annular space around the base depending upon whether a down or up-draft is used. The generator is operated by engine suction. To start it, a fire is lighted with sticks and after a few minutes the hopper filled with coke. If the engine must be cranked it is well to start if off with gasoline; if provided with a self starter the engine can be started directly on gas. The most desirable type of fuel should have a relatively high volatile content, low moisture and low ash. Low temperature coke has proved eminently suitable for these reasons. Wood charcoal also makes a good fuel. The engine is provided with a special cylinder head giving a compression ratio between 6 and 7 to 1.

The designer estimates fuel consumption to be 63 pounds per 100 miles while 0.85 gallons of water are used for the same distance.

T. K. C.

A New Principle in Grinding.—(*Chemistry and Industry*. Feb. 12, 1932). A grinding mill whose design represents a new departure from the usual type. The principle under which most grinding and pulverizing mills operate is that of exerting friction upon the material. This is usually accomplished by passing it between closely spaced moving surfaces which at the same time exert a considerable pressure. In contrast to this method, classed as pulverization by grinding and retention this new mill pulverizes by shattering and ejection. Its grinding elements consist of rows of free swinging hammers fastened between a series of discs attached to the shaft of the mill. These hammers are cast from high tensile manganese steel so tough and hard it cannot be machined. The mill operates through the medium of these swinging hammers which shatter the material in mid-air. In such a mill friction is practically eliminated. Accidental addition of large, hard objects to the mill will not result in the damage so often experienced with the present type since the hammers can freely swing back into the spaces between the discs.

T. K. C.

New Applications for Gallium.—(News Edition, *Industrial and Engineering Chemistry*.) The element Gallium was discovered in 1875 by Lecoq de Boishandran. This silver-white metal melts at about 30° C. and boils around 2000° C. Gallium is comparatively rare and until recently a unit which now costs $8.70 sold for $175. This cheapened method of preparation has been worked out by a German firm.

Gallium already has been recommended in this country as a filler for quartz thermometers to be used for high temperatures around 500° to 1000° C. Gallium readily forms alloys and as such may be used for brightening optical mirrors, and as a substitute for amalgam in filling teeth. Gallium should find application in metallic vapor lamps for unlike mercury it gives a spectrum extending into the infra-red region.

T. K. C.

The Exploding Wedge.—The *Du Pont Magazine* for Feb. 1932 describes an innovation in wedges which greatly reduces the labor usually involved in splitting logs of very tough and cross-grained wood. The steel wedge is fitted with a handle inside which is a small strong-walled chamber. In addition, there is a hole through the thicker end of the wedge and into this space the opening of the chamber passes. To operate, the hollow of the handle is loaded with a small charge of black powder, the wedge driven into the log up to the hilt, then a fuse is attached and lighted, ... The log is split wide open.

T. K. C.

High Chromium Steels.—In a paper, "High Chromium Steels in the Chemical Industry" (*Chemistry and Industry*, Vol. 51, No. 3, 1932) DR. F. M. BECKET reviews the progressive changes in the constitution of these steels as attempts have been made to discover the most suitable composition for this or that fabricating apparatus or unit.

It is well known that chromium imparts to steel pronounced rust-resisting qualities by virtue of which such alloys have won the very descriptive name "stainless." The earliest commercial stainless steels contained from 12 per cent. to 14 per cent. chromium with 0.25 per cent. to 0.40 per cent. carbon. These steels required a drastic quench from high temperatures in order to acquire their stainless properties. Such treatment also left them in a hardened condition which prevented their application in the majority of engineering processes.

Several years later another alloy appeared having 12 per cent. to 16 per cent. chromium with carbon as low as 0.12 per cent. This type could be rendered stainless without the necessity of a drastic quench and was capable of passing through many of the ordinary processes of steel fabrication.

While chromium possesses very high resistance to oxidizing influences nickel on the other hand is particularly resistant to re-

ducing conditions. It is logical to suppose that a steel containing both these elements will be an improvement over that containing either alone. The best known chromium-nickel stainless steel contains about 18 per cent. chromium, 8 per cent. nickel and less than 0.15 per cent. carbon. This particular alloy is popularly referred to as "18–8." Its success may be attributed to a number of desirable characteristics such as non-corrodibility, reasonable strength with high ductility and ease of fashioning by methods in general use. The properties of the steels mentioned thus far may be appreciably modified by the addition of tungsten, molybdenum, silicon, manganese, copper, vanadium, cobalt zirconium, and other metals. The addition of 2 per cent. to 4 per cent. tungsten considerably increases the strength of chromium-nickel steels at high temperatures.

More than ten years ago it was found that a steel containing more than 20 per cent. chromium possessed a much greater resistance to oxidation above 800° C. than steels of slightly lower chromium content. Such steel is particularly suitable in equipment exposed to sulfur-containing compounds at temperatures of 800° C. and over. As such it has found application as supporting discs in furnaces for normalising sheet steel, air waste heat recuperators, and as rabble arms in hearth sulfide roasters. These arms are called upon to withstand extremely energetic oxidizing and sulfidizing conditions. Steels of 27 per cent. to 30 per cent. chromium content have been used for valve stems and seats in pumps designed to handle acid mine waters.

Chromium-nickel steels have proved a boon to the petroleum refining industry. Their use has permitted the operation of cracking at still higher temperatures. Although an intercrystalline corrosion gradually takes place at these temperatures and in the presence of sulfur-bearing gases, it will not be long before the alloy will be improved to a degree that will eliminate this trouble. Steels of lower chromium content, 5 per cent. to 7 per cent., find application in such parts of refinery equipment not subject to excessive temperatures. Hydrogenation of petroleum takes place at temperatures and pressures higher than those used in cracking. Steels of 22 per cent. to 24 per cent. chromium and 10 per cent. to 12 per cent. nickel are being tested for this purpose.

Such is the corrosion resistance of the 18–8 steel, a full-sized sulfite pulp digester is being constructed entirely of this alloy. Even the usual lining of acid-resistant brick will be omitted. In some cases 2 per cent. to 3 per cent. molybdenum is being added to improve the chromium-nickel steels intended for use in the sulfite pulp industry.

Another interesting application of the 18–8 steel is its use in the

construction of the gasoline storage tanks for an airplane carrier. These are alternately filled with fuel and sea water and must be annealed after welding in order to preserve a uniform resistance toward corrosion. The food industries have found these steels very desirable in the construction of apparatus and containers for handling milk and milk products, such acid foods as tomato and fruit juices, pickles and vinegar. Dye vats made of stainless steel permit the use of a greater variety of dyes without danger of contamination from one another.

Three new and interesting alloys have recently been developed for the fabrication of equipment having high acid resistance. The first contains somewhat less than 60 per cent. nickel and about 20 per cent. each of molybdenum and iron, with manganese and vanadium in small amounts. This alloy is the only one of the three that can be forged, rolled or otherwise wrought and it possesses great resistance to the attack of hydrochloric acid under a wide variety of conditions. The second alloy contains about 60 per cent. nickel, 17 per cent. molybdenum, 14 per cent. chromium and 5 per cent. tungsten the remainder being iron. This alloy is formed by casting and shows a unique resistance toward chlorine and its compounds as well as phosphoric acid. The third alloy contains about 85 per cent. nickel, 10 per cent. silicon and small amounts of copper and aluminum. This alloy is also cast and will resist almost all concentrations of hot sulfuric acid outlasting lead many times.

A very recently developed steel is one containing about 18 per cent. chromium, 6 per cent. manganese, 4 per cent. nickel and 1 per cent. copper. This alloy possesses exceptional deep-drawing properties and receives in this paper its first public announcement.

T. K. C.

Sugar from Wood.—In the January 15, 1932, issue of *Journal of the Society of Chemical Industry*, H. A. ANDEN AND W. P. JASHUA describe a method of treating wood with dilute acid in order to change it over into sugar by a reaction known to chemists as hydrolysis. Hydrolysis is nothing more or less than the union of water with a substance and results in its decompositions to form other substances of a simpler nature part of the water usually accompanying each new product formed. Thus starch is hydrolyzed to sugar fats to fatty acids and glycerin, proteins such as silk or wool to the simpler amino-acids. In this particular case it is assumed the cellulose in the wood under the influence of the acid takes up water and breaks down to give a certain amount of sugar along with other substances.

Briefly the process consists in filling a vertical cylinder (percola-

tor) with fine sawdust. The sawdust is steamed for about one hour during which time the acid solution is being brought to a temperature of 180° to 190° F. Sulfuric acid at a concentration of from 0.1 per cent. to 0.2 per cent., was used in these tests. The hot acid is forced into the percolator at the bottom and is drawn off at the top. The effluent liquor contains about 2.5 per cent. to 3 per cent. of sugar. On its way to the storage tank this liquor is passed through a column of bone char in order to complete the hydrolysis begun in the sawdust column. By this process 35–40 gallons of alcohol per ton of dry wood may be produced. This corresponds to a 30 to 35 per cent. conversion of the wood into fermentable sugar. The acid consumption is about 3 per cent. of the dry wood treated and 6. per cent. of the total sugar obtained. The authors believe such yields render the process commercially feasible, the economics of the process being dependent upon the cost of raw materials and the market price of molasses.

T. K. C.

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